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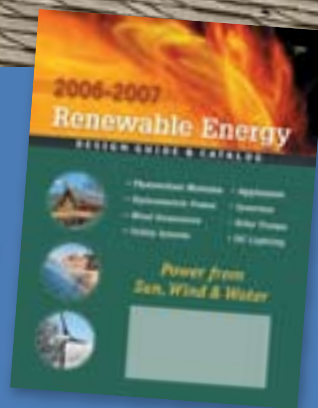
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ALAN J. KING, *Director,
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JOEL DAVIDSON, *Owner,
Solutions in Solar Electricity*

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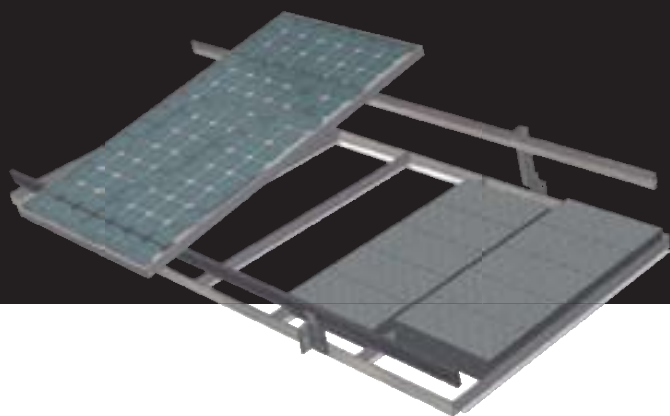
it's essential that our orders are placed and delivered correctly, and AEE always comes through. They have deep knowledge of everything they sell, equipment and systems alike. And they have that old-fashioned "can-do" attitude; you almost never hear them say "sorry, we can't do that."

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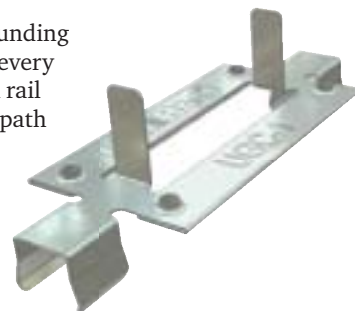
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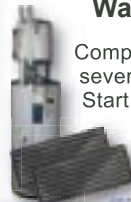
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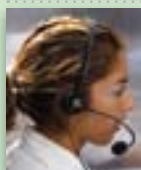
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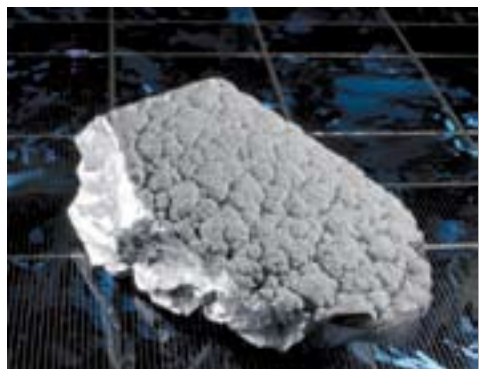
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Courtesy REC Group, www.recgroup.com



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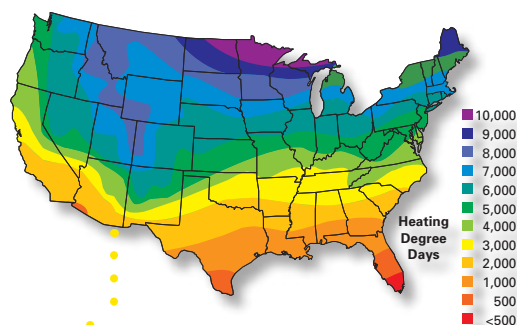


Courtesy Bergy Windpower Co.

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Photo by Shawn Schreiner



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Freedom from pollution. Of all the electrical energy sources, energy produced from renewables has the lowest environmental impact. Modern PV systems typically offset the energy it took to manufacture them in about three years, and operate without producing any pollution from that point forward.

Freedom from resource-based wars. Unlike finite supplies of fossil fuels, the power and wealth of RE are freely and equally offered to each of us—and they are inexhaustible. No war has ever been, or will ever be, fought over sunshine.

A new year is upon us, and with it comes a fresh opportunity to move ourselves, our families, and our homes in a more positive and sustainable direction. Here's to a healthy, happy, and freedom-filled new year. Best wishes from the *Home Power* crew.

Home Power publisher Richard Perez originally presented these five freedoms fifteen years ago in our April/May 1991 issue (HP22).

Think About It...

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—Marianne Williamson

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Ask the EXPERTS!

Pool Heater for Home?

I'm looking for a low-budget way to start heating some of my domestic water with the sun. Have you ever heard of someone hooking up a swimming pool heater to an extra hot water tank (in line with the regular tank) to preheat water? It seems like it would be simple to do, cheap, and safe.

Jack McKee • Bellingham, Washington

Hi Jack, Solar swimming pool heaters can be used to preheat domestic hot water, but they will only be effective in heating water to between 15°F and 20°F above ambient temperature—less if a heat exchanger is used. Plus, polypropylene (the material used in most solar pool heaters) would be questioned by many inspectors as a suitable material for potable water. In addition, plastic collectors might be questionable because of the pressure of many domestic water systems. The tubes in the pool collectors are the limiting factor for pressure considerations.

Either the pressure or health aspects, or both, might dictate a heat exchanger in the system, and this would compromise the efficiency and temperatures attained. Copper pool collectors would work fine, but they are expensive. You could attain higher temperatures with a copper absorber plate with a selective surface, but these are even more expensive. That said, if you have a low-pressure domestic water system, pool collectors could be a good preheater in the warmer months of the year, keeping the above caveats in mind.

Chuck Marken • Home Power

Using solar pool collectors to heat domestic hot water is a minimally effective strategy.



Aquatherm Industries/DOE/NREL

Small Grid-Tie Inverters

A few years ago, you ran an article on a small inverter that plugs into the wall for use with one solar-electric module. I got in touch with the manufacturer, and at the time, their units were only for 50-hertz (Hz) systems; they said that 60 Hz units would be available in about a year. I need to find this article and get in touch with them again. Can you help?

John W. Barlow III • Coolidge, Texas

Hi John. Right now there are no such inverters on the market. Soladin makes low-power 50 Hz inverters, but I have not heard of any plans to manufacture 60 Hz models for the U.S. market.

You are probably thinking about the OK4U inverters by OKE. They were selling 60 Hz models for a while. Trace Engineering had them UL-listed for U.S. installations and marketed them under the name MicroSine. But those inverters went out of production long ago.

As far as I know, the only one-module inverters available now are old ones that occasionally show up on eBay. Exeltech is working on a module inverter, but they plan to market it packaged with a PV module, not separately.

Michael Welch • Home Power

Bad Modules or Bad Design?

I have three, four-module strings feeding a single charge controller. Two of the strings are in full sun all day while the third is partially shaded early in the morning. The third string was installed later and uses a different brand of module than the first two.

I have now had two of the modules in the shaded string fail. Is it possible I have a bad batch? I think it more likely that my understanding is faulty in thinking that modules are immune to damage by shading, open or short circuits, and reasonable external voltages.

Donald Wood • via e-mail

Hello Donald, Ordinary shading from trees or buildings will not cause modules to fail. You likely ran into a bad batch of modules.

Contact the manufacturer for warranty replacement.

Modules are designed to spend a lot of their time open circuit when systems are regulating, and no damage will occur. Short-term short circuits due to mis-wiring typically will not damage modules either. That said, array short circuits will not occur in properly installed arrays and it's a situation you definitely want to avoid. Best,

Joe Schwartz • Home Power

Sparking Cables

When I connect the battery cables to my inverter, I get sparks as the last cable goes over the post of the inverter. I make the last connection on the inverter side because I'm worried about the sparking near the batteries. What is the proper procedure to connect the battery to the inverter to avoid or minimize the sparking? I also get the same problem when I disconnect, though the sparking is not nearly as bad. Thanks,

Tod Whitehurst • Newport, Virginia

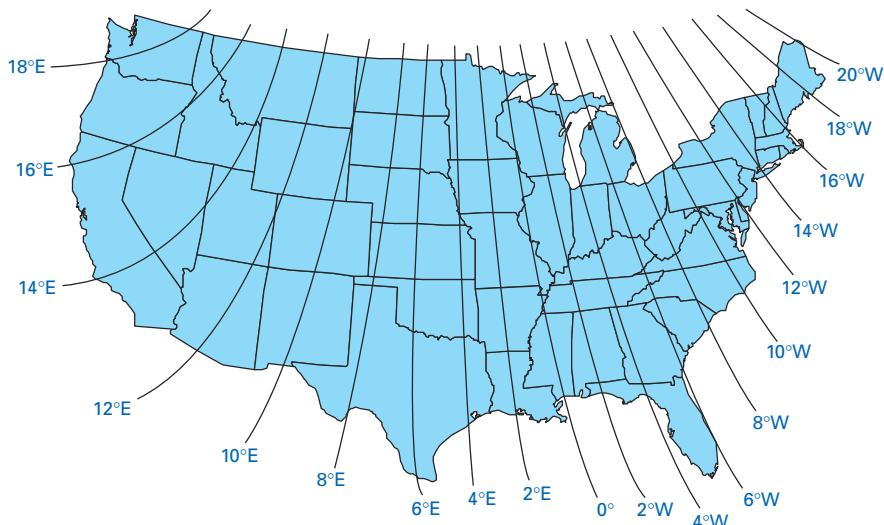
Hello Tod, The sparking you're experiencing is likely due to the inverter's capacitors charging during the initial power-up, but sparking is both undesirable and avoidable. All battery-to-inverter cabling should have either an appropriately sized DC-rated breaker (most common) or a class-T fuse used in conjunction with a DC-rated disconnect switch in the circuit. Both of these approaches provide overcurrent protection, and a means to disconnect the inverter if servicing is required. Set the breaker or switch in the open position during your cable installation, and no sparking will occur when you make your final cable termination. In systems with DC disconnect enclosures, making final wiring connections at the battery is often more convenient and poses less risk of arcing during installation.

Joe Schwartz • Home Power

Finding True South

I have been reading Home Power for several years and love it. We are getting ready to build a new house in the country and will have a grid-tied PV system installed on the south-facing roof. My

Magnetic Declination



question is how to find "true south." The magnetic declination at our location in central North Carolina is 8 degrees west. If I shoot an azimuth of 188 degrees and orient the south roof facing that azimuth

would I be close enough for decent solar exposure? Is there a better way to find true south without buying additional equipment? Thanks in advance,
Frank Stump • via e-mail

Hello Frank, You have it right. True south for your location is at 188° magnetic. Magnetic south differs from true south because magnetic north—what compasses show—is based on the large mass of magnetic material in the northern part of the Earth. This mass is not centered on the geographical pole, so for each location, there is a correction (called "declination") to convert to true north from compass/magnetic north.

I'm glad to see you're thinking of the sun when you orient your new home. Most folks just think of the view from the living room window and can wind up building a home with poor solar exposure. In fact, plus or minus 10° either way doesn't cause much loss in a fixed array (only about 2 percent).

In addition to solar-electricity, I hope you'll also consider passive solar design and solar hot water for your new home. Both of these are very effective solar technologies! Thanks for reading *Home Power*!

Richard Perez • *Home Power*



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Solar Thermal Standoff?

I run the solar thermal department for a company in Berkeley, California. We are fully convinced that flat-plate solar collectors are the way to go here where the weather is mild. Have you ever published an article comparing flat-plate solar thermal collectors to evacuated tubes?

I am getting lots of conflicting arguments from the different manufacturers. This conflicting information makes my job difficult, because (unlike PV) thermal systems are rarely metered. So a salesman can throw almost any number at the potential client and know that they will not be held fully accountable. And evacuated tubes look more high tech and modern, which clients love. I'd appreciate any comments or information on comparison tests of the two products.

Justin Weil, Sun Light and Power •
Berkeley, California

Hi Justin, You are not alone with the confusion over the endless duel between the collectors

as manufacturers fight for market share. Here are a few thoughts. The opinions are mine, but are backed up by independent test data.

"The evacuated tube is always perpendicular to the sun and therefore the SRCC is not a good guide." Testing labs include the incident angle modifier of all collectors tested. The test data is apples to apples, and I have never experienced it being anything but fair.

"The evacuated tubes put out more per square foot of roof space." Generally, this is not true except in extreme conditions—either very high temperature inlet or in extremely cold climates.

I believe that evacuated tube collectors can be the best value for use in certain situations, but those situations are scarce in the United States. When it comes to pressurized domestic hot water systems, I haven't ever seen a case where any evacuated tube collector (because of their higher cost per square foot) can compete on the basis of Btu produced per year, per dollar, with a well-made flat-plate collector in any state but Alaska.

Because of the never-ending rise in the price of copper, evacuated tube collectors may be more cost-competitive in the future—they are typically made with less copper. Meanwhile, look for a solar water heating system sizing article in the near future that will address interpreting SRCC data to some extent. And we're on the hunt for an article comparing flat-plate and tube collectors. Cheers,

Chuck Marken • *Home Power*



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Need Nukes?

As a new subscriber, I've been impressed with the overall quality of the magazine, and the technical accuracy and thoroughness of its authors and editors. But I was stunned by Michael Welch's no-nuke piece ("Nuclear Energy & Climate Change," HP112).

Welch has his political position with respect to nuclear power highly entrenched, and appears only able to quote antinuclear organizations in making his arguments. The fact is, increasingly we are seeing enlightened environmental advocates coming around to the fact that we will need nuclear energy to help control global climate change. James Lovelock, who gave us the Gaia theory of a living Earth, Stuart Brand of the *Whole Earth Catalog*, and Patrick Moore, who helped found Greenpeace, now all support expanded use of nuclear energy.

Certainly we need to increase energy efficiency, we need to use renewable energy sources where they make sense, and we need to curb our appetite for energy. But other than according to the most fringe studies, none of that will be adequate. The world will need substantial new energy supplies, particularly ones that can replace fossil fuel burning, and nuclear energy has ended up on everyone's plate. The time for ideologues like Welch has passed. What we need now are practical solutions that do not have to pass the politically correct litmus test.

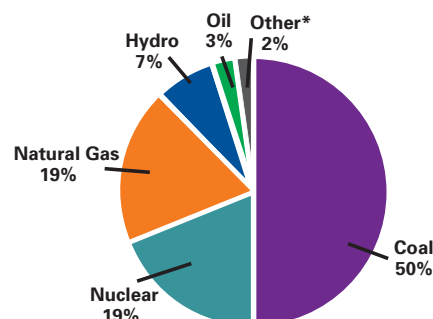
Edwin A. Karlow •
Riverside, California

Hello Edwin, For 20 years, *Home Power's* mission has been to promote the expanded use of both renewable energy and energy efficiency to lessen our reliance on fossil and nuclear generation sources. That's our goal. Renewables are superior to both of these traditional fuels in terms of environmental costs, and they offer us the opportunity to create a forward-thinking energy plan that is both safe and sustainable in the long term.

The *Home Power* community, our readers and our staff, has always represented a diverse and evolving voice exploring the best ways to increase the use of renewables. One extraordinary thing about renewables is that they can work for everyone. It's a case of technology cutting through the usual barriers (political, social, etc.) that tend to be divisive.

The bottom line of your letter serves as a great reality check. According to the U.S. Department of Energy, if we factor out large-scale hydro-electricity (which accounts for about 7 percent of U.S. electricity generation), renewables, including solar, wind, and

National Fuel Mix



*"Other" includes generation by agricultural waste, batteries, chemicals, geothermal, hydrogen, landfill gas recovery, municipal solid waste, non-wood waste, pitch, purchased steam, solar, sulfur, wind, and wood.

Source: U.S. Dept. of Energy, Energy Information Administration (EIA), 2005 preliminary data

biomass, currently account for only 2 percent of our electricity generation. In the United States, coal dominates all other fuel sources for electricity, representing 50 percent of the energy mix. Nuclear and natural gas both have a 19 percent share. Energy use is expanding here in the United States, and even more rapidly in countries like China and India. In these terms, renewables are currently small fish in a *very* big pond.

As both you and Michael Welch point out, energy efficiency is the best option to slow our need for increased generation capacity. Compared to increased generation, efficiency measures can be implemented quickly.

Paul Robert's excellent book, *The End of Oil*, has a great chapter tracing humanity's large-scale energy shifts—from wood, to coal, to oil. The fact that we've made these shifts in the past leaves me confident that we can successfully do it again. Just as renewables currently make up a small portion of our total energy mix, the same could be said of coal at one point in our energy history. While fossil fuels and nuclear energy will undoubtedly continue to make up the majority of our energy mix in the near future, all of *Home Power's* efforts are aimed toward ensuring that the next major shift is to renewables. Thanks for your thought-provoking letter. Best,

Joe Schwartz • *Home Power*

Hello Edwin, The idea that environmentalists are moving toward embracing nuclear power is pure fiction. You cite the same names constantly circulated by the nuclear industry. The reality is that Patrick Moore hasn't been an environmentalist for 20 years and is now a paid consultant to the Nuclear Energy Institute (and his Web site regularly attacks

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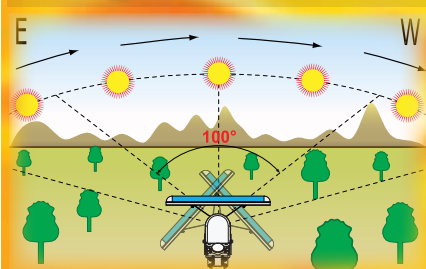
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This sounds like bad news or, at best, no news, so why bother? A couple of reasons. First, the likelihood that any one consumer would get what they paid for would improve from near-zero to near-100 percent, a tactic far more likely to build market confidence than the occasional pleasant surprise that now characterizes "the day after." Second, system designers could eliminate that actual-versus-nameplate fudge factor from their performance estimates. Finally, installers would eliminate one more asterisk: "Yeah, it says 150 watts on the module, but you won't actually see that from your system..."

Managing expectations is much easier when you start from a realistic base. "Okay," you say, "but if we go

to a performance-based (i.e., energy-based) incentive, module power will be irrelevant." Baloney. You don't get a watt-hour until you have a watt. Every conventional power plant, be it diesel-based distributed generation or natural gas-fired central station, has a power rating that is the basis for predicting energy production.

One minor correction to the article. The statement "...the PV module rating method be changed to one that rates PVs at their minimum output, rather than at standard test conditions (STC)..." is not quite accurate. Our proposal is that the module nameplate should still be measured at STC, and represent the minimum of the manufacturer's rating tolerance. The 150 watt, plus or minus 10 percent module mentioned in the example would instead be rated at 135 watts, -0 percent / +10 percent (or tighter, +10% being the maximum allowed by UL listing).

Whether modules should be rated at STC, PTC, or some other conditions is a separate, though important, discussion. Several reports on our PIER project Web site (www.pierminigrid.showdata.org) discuss this topic in detail. By the way, the subscript "p" in Wp stands for "peak"

and is conventionally used to represent the STC DC rating of a module or a system. Why anyone would rate an AC power system in DC watts—which is sort of like rating a portable AC generator in horsepower—is fodder for yet another article. Kind regards,

Chuck Whitaker, Behnke,
Erdman, and Whitaker Engineering, Inc. •
San Ramon, California

Thanks to you, Chuck, for providing testimony to the California Energy Commission concerning this issue. Without you and your company stepping forward to put this on the record, I would not have had credibility on this subject. Best,

Don Loweberg •
Independent Power Providers

Internet RE Forums

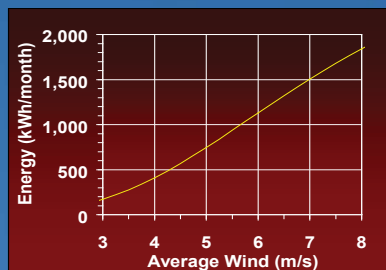
Have you found any good online forums for discussing renewable energy?

Bill Bar • via e-mail

Hi Bill, Here is one solar-electric (photovoltaic; PV) systems listserv that has lots of good people on it, but very little traffic: http://listserv.repp.org/mailman/listinfo/pvusers_listserv.repp.org.

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This is pretty good for microhydro systems: www.groups.yahoo.com/group/microhydro. And these folks have a nice wind energy systems list: www.groups.yahoo.com/group/awea-wind-home.

Michael Welch • *Home Power*

Solar Hot Air

I am in the process of building a home high in the Rockies. I would like to review the options of using solar air heating. Have you tested or reviewed any of the products? I would like to compare as many as possible, so anything you send in getting me directed on this research would be appreciated. Thanks,

James Pope • Fort Garland, Colorado

Hi James, To get started, check out *HP98* and *HP99* for articles on air collectors and their installation. Don't have the back issues? Go to our Web site, click on the "HP Archive" and enter the issue number in the search box. Digital back issues are \$5. There is also a free downloadable article about a homebuilt solar hot air system—click on "Magazine," "Files & Downloads," and then on "Solar Hot Water & Space Heating." Cheers,

Chuck Marken • *Home Power*



Zoning Woes

RE education is always needed. Eight months ago, the Dubuque County, Iowa, Board of Supervisors decided they needed a zoning category for wind turbine towers. The first question was "Why?" after many years and many towers already up and running. The simple answers were "bird kill, looks, liability for damage from falling towers, and because small residential turbines are starting to become very common in parts of Iowa."

After many monthly meetings the zoning board suggested "an environmental study for bird kill for each tower permit, a 110 percent of tower height setback, appearance and paint color requirements, TV and microwave interference studies, and a wind noise study for each system." The big problem was that the zoning board got most of their info piecemeal from many different commercial wind generator tower regulations across the country. I supplied information from many past studies on bird kill, noise, and setbacks (drawing from Mick Sagrillo's Web site, federal and Iowa Department of Natural Resources, and the American Wind Energy Association), showing these non-issues were already studied to death.

The tower owner in this case did an excellent job of education by inviting the Board of Supervisors to his future site in the country (8 acres), and two of the three supervisors toured the site twice. The owner received letters from state senators and representatives in support of his project and read them at the meetings. I wrote editorials for eastern Iowa and local papers comparing this problem to Don



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Quixote's fighting mythical windmills. All this education paid off—sort of. The bird kill issue was temporarily dropped until it could be studied further. The setback was reduced to 100 percent of tower plus turbine height, but the request for all future towers and turbines in Dubuque county must still go before the county board of adjustment, where public input could very easily stop any residential wind project.

As to humor and education, years ago the same county tried to stop a big solar heating project by requiring all solar collectors to be under a roof and inside a building because "it is a boiler system" and could explode. Education is a big part of getting RE mainstreamed!

Tom Snyder • Dyersville, Iowa

Masonry Heaters

Dear *Home Power*, I read the article on rocket mass heaters in *HP115* and noted that you mentioned that this type of unit is not commercially available and that the experimenters should take caution. I agree with this statement 100 percent. People should not take chances when their homes and lives could be put in danger by uninformed experimenters.

From the article, I noted many similarities between rocket heaters and commercially available masonry heaters. A masonry heater uses a wood charge, plenty of air, a huge amount of thermal mass, and an extended chimney structure to extract heat from a high-intensity fire. Masonry heaters are site built, but the internal components can be purchased from reputable manufacturers to create a stable heating platform. They can also be built with glass doors so that you can watch the 1,500°F fire. If *HP* readers want a similar product, with similar features, built by a professional, they can contact the Masonry Heaters Association (<http://mha-net.org>). For a manufacturer of internal components, they can contact companies like Temp Cast (www.tempcast.com). Others are available. Masonry heaters are also recognized as being incredibly efficient, just as the rocket mass heater claims to be.

Larry Tabor • Palisades, New York

Errata

The diagram presented in "Big Heat from a Small Stove," in *HP115* was intended as a conceptual drawing to convey the general components and workings of a rocket mass

heater stove. As such, it should not be used as a construction drawing. For step-by-step instructions, read *Rocket Mass Heaters: Superefficient Woodstoves You Can Build (and Snuggle Up To)* by Ianto Evans and Leslie Jackson, available for order online at www.rocketstoves.com.

In "Biofuels: Revolution or Ruse?" (*HP115*) by David Max and Richard Engel, the text on page 49, first column, second paragraph, should have read: "Converting every acre of land in the United States to soybean production would replace barely half of our current gasoline and diesel fuel consumption."



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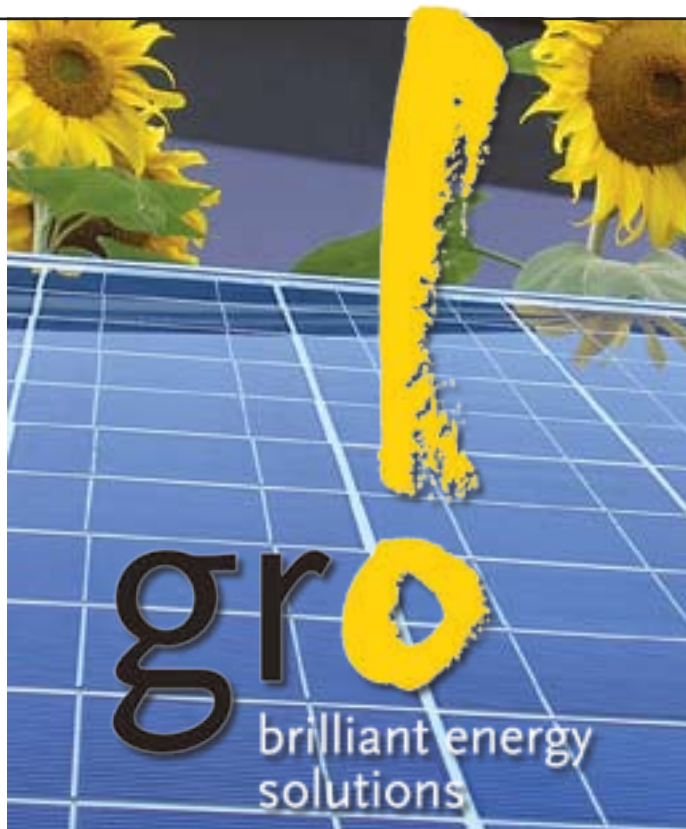
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United Bicycle Institute (UBI) owner Ron Sutphin's reason for going solar was simple on the surface: "UBI supports sustainable transportation through our educational efforts in the bicycle industry. Now, we're supporting sustainable energy too." But when the rubber met the road, Ron's decision to go solar had as much to do with greenbacks as it did his with his green ethics.

Ron Sutphin, owner of United Bicycle Institute.



SMALL BUSINESS, SOLAR SUCCESS

ALL THE INCENTIVES YOU'LL NEED

Joe Schwartz

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From Solar to Cycling

Ron took an interest in solar energy technology in the mid-1980s, and had seriously considered a career developing communities with energy efficient buildings powered by renewables. But these plans took another turn in 1986 when he was presented with the opportunity to buy the United Bicycle Institute in Ashland, Oregon, and administer its business and educational programs. So Ron sidelined his interest in renewable energy (RE) and turned his attention toward sustainable transportation, focusing on cycling education, training bike mechanics, and successfully building a small business. This past year, UBI certified more than 500 mechanics and frame builders, and currently has more graduates working in the field than any other bike mechanic school in the United States.

A few years ago, UBI's profitability put Ron in a position to invest some additional capital into his business. Their building had been renovated and upgraded for energy efficiency, student workbenches were outfitted with the latest bike tools, and the shop was well supplied with equipment.



UBI's solar-electric system provides 50 percent of the electricity used in the building, and the remainder is purchased from the local utility's green energy program.



UBI program administrator John Baxter, who had been a frequent participant in Ashland's annual solar home tour, suggested that they investigate the cost-effectiveness of a solar-electric system to power the Institute. That suggestion was all the motivation that Ron needed to rekindle his interest in solar energy.

Smart Business Decisions

The City of Ashland operates its own municipal electric utility, and has always been a friendly environment for grid-tied solar-electric systems. In 1996, Ashland implemented a citywide net metering policy. This voluntary action occurred three years before the rest of Oregon's investor-owned utilities were required to participate in a mandatory net metering program passed unanimously by both Oregon's House and Senate. Net metering allows both homeowners and businesses to offset monthly or annual electricity use with site-generated renewable energy, with the utility paying the participating customer the retail rate per kilowatt-hour (KWH) for RE generated.





Top: Installer Eric Grisen wraps up the inverter, disconnect, and wire raceway mounting.
Bottom: The completed power wall—ready to go.

Ron's first call was to Larry Giardina, a conservation analyst for the City. Ashland currently offers a cash incentive of \$2.25 per installed watt for grid-tied solar-electric systems, with a maximum incentive of \$10,000 per site. To receive incentive money, the City requires that the proposed PV array location is unshaded between 10 AM and 2 PM. The site must also receive 75 percent of the total solar resource available when compared to a completely unshaded, south-facing array on a year-round basis. UBI's large south-facing roof has *no* shading, even in the winter, when the sun's path is at its lowest point in the sky—making it a perfect place for a high-performance PV system.

Ron's next call was to his accountant. Federal business tax codes allow for a five-year accelerated depreciation schedule for PV equipment. At the time, a 10 percent federal tax credit also was available for commercial PV systems. Now, business owners can take a federal tax credit equal to 30 percent of their solar equipment and installation costs for systems brought online in 2006 and 2007.

In addition to the corporate depreciation benefit and the federal tax credit, Oregon's Department of Energy



Mounted on the roof, the array is completely unshaded throughout the year—optimal for solar energy production.

provides a business energy tax credit of 35 percent taken over five years for commercial PV systems. When Ron and his accountant considered the incentive available from the city, the state and federal tax credits, and the accelerated depreciation schedule, investing in PV seemed like a no-brainer. "Our business makes enough money to pay a pretty big tax bill, and the tax credit from the state of Oregon is the same as cash back," says Ron. "It's the only way I get to vote with my tax dollar, so I decided to go for it."

Tech Specs

Overview

System type: Batteryless, grid-tie PV

Location: Ashland, Oregon

Solar resource: 4.9 average daily peak sun-hours

Production: 990 AC KWH per month average

Utility electricity offset: 50 percent

Photovoltaics

Modules: 48 Sharp NT-175U1, 175 W STC, 35.4 Vmp

Array: Six, eight-module series strings (two per inverter), 1,050 W STC each, 283.2 Vmp, 8,400 W STC total

Array installation: Direct Power & Water RGM mounts installed on south-facing roof, elevated 30-degree tilt angle

DC array disconnects: Three, Square D H361NRB

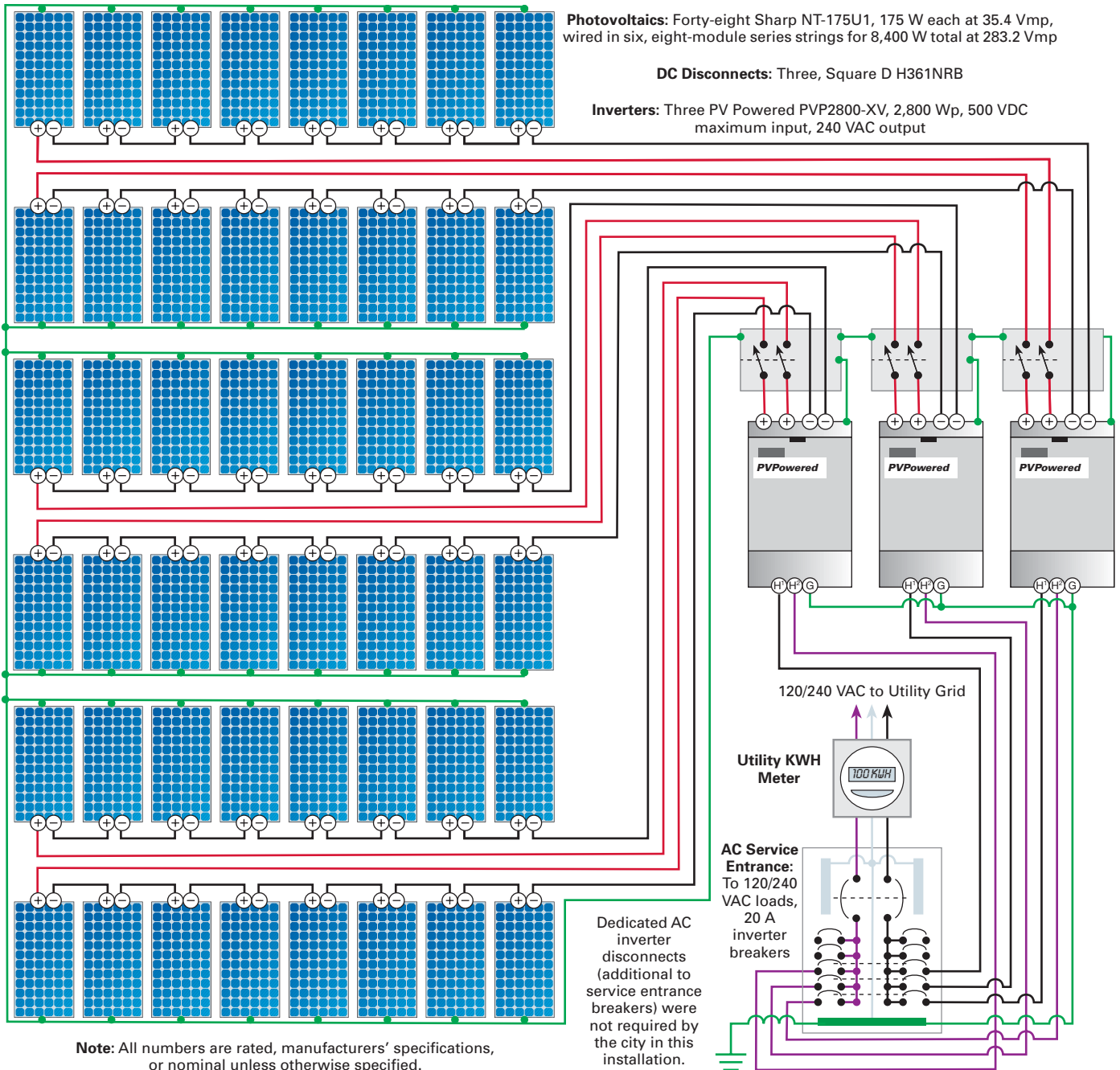
AC disconnects: 20 A, 2-pole breakers

Balance of System

Inverters: Three, PV Powered PVP2800-XV, 2,800 Wp, 170 to 450 VDC operating range, 500 VDC maximum, 240 VAC output

System performance metering: Built-in inverter displays; utility KWH meter

UBI Batteryless Grid-Tie Photovoltaic (PV) System



Racking and stacking the solar-electric modules.



Sizing the System

For years, Ron had read in *Home Power* about RE systems designed and installed by local, long-time installer Bob-O Schultze of Electron Connection. After evaluating the solar exposure at the site and examining the structural details of the building, he and Bob-O pored over a few years of electrical bills to get a good idea of how much electricity the Institute was using, and talked about Ron's expectations for the system. The previous year, UBI had consumed close to 24,000 kilowatt-hours (KWH) of electricity. Ron decided that offsetting half of the Institute's grid-electricity use with solar was a good initial goal.

Small Business Solar—Step by Step

With the bevy of incentives available, like tax credits and rebates, investing in a solar-electric system for your business is a smart financial strategy. Here's how to get started.

Find a qualified local installer. While an experienced installer is essential for high-performance commercial PV system design and installation, most PV installation companies also have substantial experience in handling the logistics of applying for and maximizing a system's financial incentives. An experienced installer will likely be your primary guide through the list of financial incentives that are available to you.

Check out the Installers Directory in each issue of *Home Power* magazine or on the Web at: www.homepower.com, www.renewableenergyaccess.com, www.nabcep.org, and www.findsolar.com. When selecting an installation company, follow the same steps you would with any other building contractor—get more than one bid for your project, and get references from past clients.

Seek out incentives. Find comprehensive and current information on federal, state, and utility rebate and tax incentives for both commercial and residential renewable energy and energy efficiency projects at the Database of State Incentives for Renewable Energy (DSIRE) Web site (www.dsireusa.org).

- Many states offer tax credits for business PV systems. Contact your state energy office for more information. If your company does not have enough of a tax liability to maximize state tax credits, check into pass-through options, which may allow you to partner with another business to maximize the tax incentive for your PV investment.
- New federal tax credits have been implemented for both residential and commercial solar-electric systems commissioned in 2006 and 2007, and legislative work is currently underway to extend the tax credits beyond 2007. Residential PV tax credits max out at \$2,000 per system, but incentives for businesses are even more attractive—30 percent of the installed system cost with no cap.
- Even some electric utilities offer financial rebates for commercial PV system installations. Check the DSIRE Web site, or contact your local utility and state energy office for PV incentive program details. And don't forget to keep an eye out for weatherization and appliance upgrade incentives as well. It's far more cost effective to *save* energy than to generate it, and every dollar you spend on upgrading the energy efficiency of your business can save you roughly \$3 to \$5 in PV system component costs.

Make an appointment with your accountant. Your business accountant can help you determine how your company's tax status will influence taking advantage of incentives and accelerated depreciation schedules. Many states have property tax exemptions for renewable energy equipment as well. Getting your accountant involved in your project from the beginning will help greatly with your system's financial planning.

During that time, Ashland's solar incentive was \$3.50 per installed watt, with a cap of \$10,500. A 3-kilowatt (KW) PV system would max out the rebate. With UBI's annual electricity usage in mind, Bob-O ran some preliminary numbers and it became apparent that a 3 KW system would generate approximately 350 AC KWH per month at the site, falling far short of Ron's goal of offsetting 50 percent of UBI's annual electricity use.

"When I looked at the numbers, 3 KW wasn't going to make a big enough dent in our electrical usage. So I was like, OK, what's it going to take to get this over 50 percent?" says Ron. After running some more numbers, it became clear that if Ron wanted to hit the 50 percent mark, an 8 KW PV array would need to be installed, and that any PV installed over 3 KW would not receive an incentive from the city.

"It made me swallow kind of hard at first because it was a huge outlay of cash," says Ron, who has a reputation around town as being a pragmatic guy who doesn't do something unless it makes sound economic sense. As he gathered more financial details on the proposed system, the benefits—both ecological and economic—made it an easy decision to move forward with the system. At the time of writing, UBI's PV system has produced more than 20,000 AC KWH and has offset 40,160 pounds of carbon dioxide, a notorious contributor to global warming.

Solar Savings

Electron Connection's final system design specified a 48-module, 8.4 KW solar-electric array feeding three PV Powered 2,800-watt inverters. The inverters were chosen in part because they are manufactured in Oregon, and their selection helps support RE equipment manufacturing in the state. The installation was straightforward for Bob-O and apprentice Eric Grisen. Direct Power & Water mounts were set at a tilt angle of 30 degrees to maximize summer energy harvest. Because Ashland has very infrequent utility interruptions, a batteryless system with no provision for backup was installed. Batteryless PV systems require no ongoing maintenance, which was a plus for the busy UBI staff.

UBI's PV system came online on April 29, 2005, and has been offsetting 50 percent of the Institute's annual electrical use—just what Ron had expected. During the summer months, electric bills have been as low as \$28, down from \$200 to \$250 a month before the system was installed.

"If you have a business and you're at all profitable—and you own the building—investing in PV makes good financial sense," says Ron. "The only way it couldn't be an absolute winner is if I wasn't operating profitably, and in that case what would I be doing investing in something like PV anyway?"

Besides supplying their building with clean, renewable energy, another benefit for Ron and his business is the positive PR the system generates. "There's a bike component manufacturer down in Redding, California, I called with a bike tech question. Halfway through the conversation he interrupted and said, 'You guys just did that solar thing up there, didn't ya? I'm thinking of doing the same thing too.'"

PV System Payback Analysis

Costs	First Year	Second Year	Third Year	Fourth Year	Fifth Year	Sixth Year	Totals
Installed system cost	\$52,080	–	–	–	–	–	\$52,080
City of Ashland PV rebate	-10,500						-10,500
Initial Cash Expenditure	\$41,580						
Tax Benefits & Energy Savings							
Oregon tax credit ¹	\$5,208	\$5,208	\$2,604	\$2,604	\$2,604	–	\$18,228
Federal tax credit ²	5,208	–	–	–	–	–	5,208
Federal depreciation ³ (estimated)	2,686	4,298	2,579	1,547	1,547	774	13,431
Energy savings ⁴ (estimated)	831	831	831	831	831	831	4,986
Running Net Cost	\$27,647	\$17,310	\$11,296	\$6,314	\$1,332	-\$273	

¹If system cost is greater than \$20,000,
35% credit must be taken over five years
(10%, 10%, 5%, 5% & 5%)

²10% of system cost (now 30%)

³Assumes 34% federal tax bracket

⁴Calculated at \$0.07 per KWH

Table data courtesy of Electron Connection

"I think, if anything, I underestimated how much goodwill there was coming from our students and incidental sources," says Ron. "The students seem to really dig it. Some of them are so excited it's hard to get them to focus back on the bikes."

Access

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Courtesy BP Solar, www.bp.com

Clean Energy from Cradle to Cradle

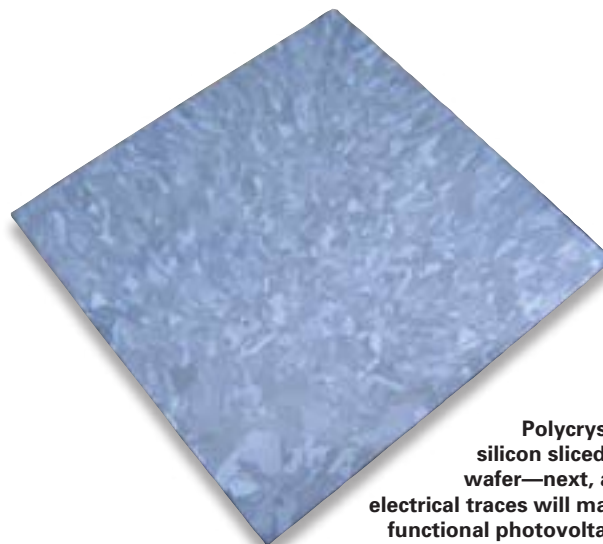
Scott Sklar

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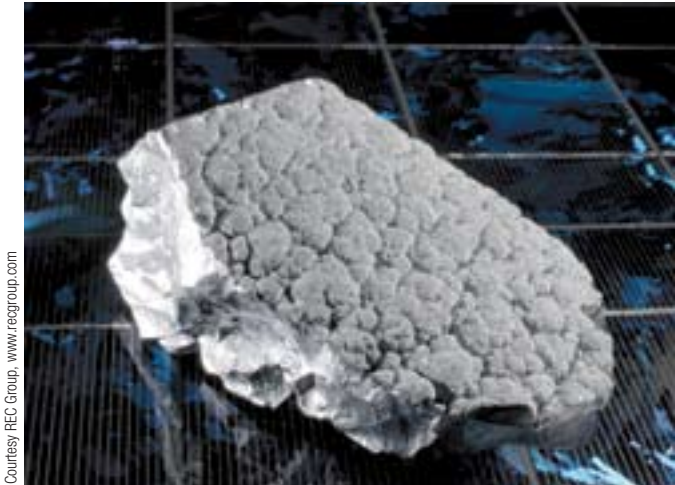
Photovoltaic (PV) technology has the reputation of being a pollution-free energy source that can provide clean electricity for decades. With no emissions, no noise, and no moving parts to maintain, PV technology appears to be a dream come true. But skeptics point out that the manufacture of this sunlight-harvesting equipment is an energy-intensive, polluting process, and that the solar industry couldn't survive without subsidies. Renewable energy analyst Scott Sklar sheds a little light on the subject.

PV Energy Payback

One of the biggest questions people ask about solar-electric systems has to do with energy payback: Does it take more energy to make a PV module than the PV will actually produce in its lifetime? In 2005, the National Renewable Energy Laboratory completed an analysis that compared the amount of energy required to manufacture PV modules to their energy output. After the first 18 to 36 months (depending on the type of PV technology and the site), PVs have produced as much energy as was used in their manufacture, and thereafter all the energy generated is "net positive." Fossil-fuel-based energy sources like coal or natural gas require the ongoing use of finite resources. These energy generation approaches will never achieve "net positive" energy production.



Polycrystalline silicon sliced into a wafer—next, adding electrical traces will make it a functional photovoltaic cell.



Courtesy REC Group, www.recgroup.com

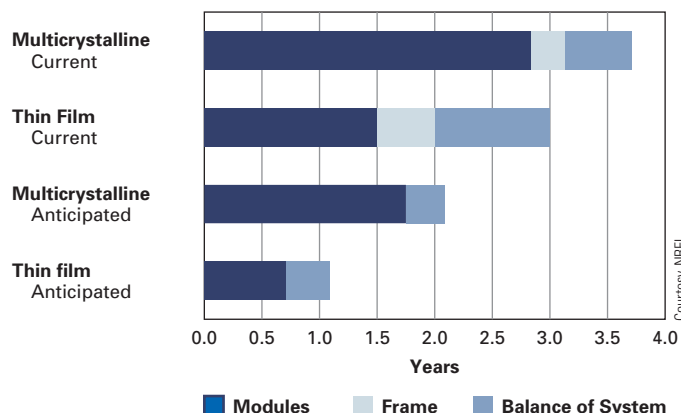
A nugget of metallurgical-grade silicon, the "active ingredient" in a photovoltaic module.

Environmental Effects

What about the overall environmental impact of photovoltaics compared to other energy technologies? The most recent analysis was completed by Associate Professor David Bainbridge at the U.S. College of International Business in San Diego. In the October 2004 issue of *Solar Today*, Bainbridge compared renewable technologies with conventional energy technologies—coal, natural gas, nuclear, and petroleum—looking at their respective impacts, like emissions produced (including global warming gases), air and water pollution, habitat loss, and effects on human and animal health.

Bainbridge's conclusion: "With assumed [PV] life expectancies of 30 years, and taking into account the fossil-fuel-based energy used in [their] manufacture, 87 to 97 percent of the energy that PV systems generate won't be plagued by pollution, greenhouse gases, and depletion of resources."

Energy Payback of PV Systems



Manufacturing & Recycling

Producing the materials that comprise PV cells and modules (silicon, aluminum, glass, and plastic polymers) is a very energy intensive process, and cell and module manufacturing require the use of a variety of hazardous chemicals. (The computer chip and circuit board industries use many of the same chemicals.)

The majority of the newer PV manufacturing facilities are among the most efficient, modern, high-tech plants in the world. Most of them comply with the globally approved ISO (International Organization for Standardization) 9000\9001 standard, which addresses facilities' health technology, environment, wastes, and safety, among other issues.

Module Manufacturing

Polysilicon solar cells make up the lion's share of PV production. The life cycle of a silicon solar cell starts with silicon dioxide (SiO_2), which is reduced in an electric furnace to produce metallurgical-grade silicon that's 99% pure. It is then further purified to obtain electronic-grade polysilicon (>99.99999% purity), which is used as a "feedstock" for making the solar silicon wafer.

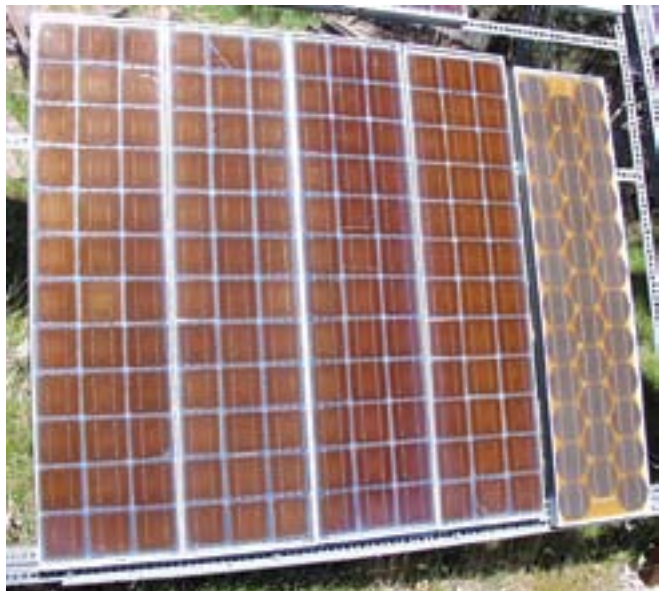
Casting. The feedstock is melted in a crucible, and pulled or grown as a cylinder (monocrystalline), or directionally solidified (polycrystalline). During the melting process, in most methods, a small quantity of boron is mixed to make the silicon p-type. The ingots that result are cut to the needed dimensions.

Wafering. After casting, ingots are sawn into thin slices (called wafers) by state-of-the-art wire saws. Most manufacturers produce wafers approximately 250 microns thick. Wafers are then cleaned in industrial soap and other chemical solutions to remove any defects introduced during the sawing process.

Cell Production. Since wafers are pre-doped with boron (p-type), an n-type material (usually phosphorus) is diffused into the wafer to achieve the p-n junction. Then a very thin antireflective coating is applied to the surface, which makes the cell appear dark. Next, the conductors are deposited on the surfaces to complete the electrical circuit. Silver and aluminum are the most widely used metals for contact formation.

Module Assembly. The cells are laid out on a substrate and interconnected. Then glass or plastic is placed on top of the cells. Finally, the edges are protected with frames and sealed to the rest of the module. Under sunlight, each cell produces a low voltage (typically about 0.5 volts) and a relatively high amperage (5 to 8 amps). Cells are generally connected in series, which increases the module's voltage. Most PV modules are built using a strong tempered-glass cover, and the cells are laminated between sheets of a protective polymer and a strong back-sheet to avoid environmental damage. All top manufacturers' modules carry 20- to 25-year warranties.

—Courtesy of Jean Posbic • BP Solar



These 23-year-old ARCO modules still make useful energy. Modern PV modules are manufactured to resist the discoloration show here.

Manufacturing plants must reclaim effluents they produce, and either recycle them under standard practices or dispose of them under strict international standards.

After a PV system is manufactured, assembled, and installed, at what point do the modules and components become waste products—and what happens to them? Because PV modules can last for 50 years or more, very few have hit the waste stream so far. But a study presented at a June 2005 conference in Barcelona, Spain, predicts that in 2040, Europe will have 33,500 tons of waste PV modules to deal with.

Several companies have plans or technology in place for recycling PV modules. For instance, in 2003, Sharp Solar developed recycling technology that melts and processes the silicon cell material from used PV modules into new cells for new modules. Deutsche Solar has a pilot plant that recovers used silicon wafers for remanufacture. Their process produces wafers with one-third of the embodied energy of wafers made from virgin materials, further reducing the energy payback time for PV modules. Glass and metals from used modules are also readily recyclable, though recycling them has a less dramatic impact on the energy and cost payback.

Comparing Costs

What is the “real” delivered cost of photovoltaics versus conventional energy technologies? Does the use of photovoltaics and the subsidies supporting them just distort the energy market and create a chronic dependency of the solar energy industry on subsidies?

First of all, the energy market is not a free market. Our taxes subsidize nonrenewable energy by tens of billions of dollars per year, including well-drilling costs, oil and gas depletion allowances, special treatment for coal royalties, liability limits for nuclear energy (the Price-Anderson Act), and R&D on coal, oil, and nuclear energy resources. And this

does not even count the military requirements to protect oil and natural gas production and shipping, or nuclear waste storage.

All energy technologies are subsidized to some degree. Could photovoltaics compete today if all the subsidies for conventional energy technologies were done away with? Yes. But will our political system ever stop subsidizing mature energy companies with mature energy technologies in mature markets? That’s not likely.

So how do we compensate for the bias that favors conventional energy technologies? By providing tax incentives, procurement and portfolio standards, emissions allowances, and demonstration grants—all common tools of federal, state, and local governments. Rather than being a reflection on the viability of solar technology, these incentives are simply a reflection of our political system and how it works.

More PV, Less Pollution

A typical U.S. household consumes about 900 kilowatt-hours (KWH) of electricity per month. Compared to coal-generated electricity, a PV system designed to generate 1,000 KWH per month will reduce carbon dioxide emissions (a major contributor to global warming) by about 1,400 pounds, and keep 8 pounds of sulfur dioxide and 5 pounds of nitrogen oxides out of the atmosphere—every month.

Because PV modules are net-positive energy sources, after they recoup the energy consumed during their manufacture, they generate pollution-free electricity over the rest over their operational lifetimes. They do all this right on your rooftop. And that payback—emissions-free electricity, energy independence, cleaner air—is priceless.

Access

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“PV Payback,” Karl Knapp & Theresa Jester in *HP80*



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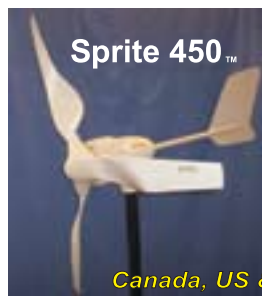
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Erin Moore Bean

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Cell phones, PDAs, MP3 players, digital cameras, GPS equipment—if you're like most of us, you probably own at least two or three portable electronic devices. They allow you to take your world with you anywhere. But whether you're spending a day at the beach or trekking in the Himalayas, when the battery of your handheld gear is fully discharged, you're stuck searching for an electrical outlet.

Luckily, the explosion of portable gadgets on the market has been matched by an increase in portable and renewable ways to recharge them. The two most common sources of portable electricity are solar-electric (photovoltaic; PV) modules and hand-crank generators. And just as cell phones have shrunk from analog bricks to slim digital powerhouses, mobile energy sources are smaller, lighter, and better designed than ever before.

Portable energy sources are convenient for experienced renewable energy (RE) users, but they're also a great way to

introduce RE-skeptical family members and friends to some of the benefits of solar energy. The first time your cell phone works—and theirs doesn't—the practicality of portable solar electricity will quickly get their attention.

Mobile charging devices are cool, but in addition to being fun to use, they can also reduce the use and waste associated with disposable batteries. Rather than carrying an extra set of alkaline batteries—adding not only additional waste but additional weight to your load—with portable solar electricity, you can carry just one set of rechargeables, or charge many other devices, like cell phones or MP3 players, directly.

Before you spend your hard-earned cash on a portable charging source, consider several factors. First, decide what devices you'll be charging. Most small gear, like cell phones and MP3 players, need a charger that produces at least 4 watts. Larger devices, like laptop computers, have higher energy needs—12 watts or more. The higher the wattage of your portable energy source, the shorter your charge times will be.

SOLAR OPTIONS



BRUNTON SOLARPORT 4.4

(www.brunton.com, \$119)

A great introduction to portable solar electricity, the SolarPort's hard plastic shell opens like a book to reveal two polycrystalline solar-electric modules. It's 9 inches tall, 6 inches wide, and only 1.5 inches thick—as big as your favorite field guide, and just as useful. Its 4.4-watt maximum output makes it a perfect pairing with MP3 players, cell phones, and other small electronics. It also comes equipped with adapters for charging via a USB cable (for portable MP3 players). A battery charger for AA and AAA batteries is included. At just under 1 pound, it's a no-brainer to toss this charger into your pack. Amount of time to charge a cell phone: 2 to 4 hours.

POWERFILM F-SERIES FOLDABLE SOLAR CHARGERS

(www.powerfilmsolar.com, \$150–\$450)

The next step up in portable solar electricity, PowerFilm's foldable solar-electric chargers unfold like photovoltaic picnic blankets. PowerFilm offers several sizes; the larger the array, the greater its output, and the more quickly it will charge your electronics. At the low end, the F15-300 offers 11 by 25.5 inches of 5-watt solar real estate, which can effectively charge small handheld devices, as well as provide a "trickle charge" for your car battery. Unfold it on the dash and plug it into your cigarette lighter receptacle when ditching your car for extended periods, and it'll maintain a minimum charge until you return.



Next, decide how you'll be using your portable solar or wind-up charger. If you plan to use it frequently, the PV units are a good choice, as long as you remember to plug them in and set them in the sun a few hours before your equipment's battery is fully discharged! If emergency backup is what you're after, consider wind-up devices—their charge times are limited only to the amount of elbow grease you can provide.

Be sure to check out how you'll connect your electronics to your charger. Some portable chargers come with cigarette lighter-type receptacles, and you may have to buy additional adapters. Before you leave the comforts of home (and its AC-charging capabilities), test your new portable charger with each device so there will be no surprises when you're in the field.

When you're trying out your new equipment, be sure to note the conditions and the amount of time needed to fully recharge your electronics. Your cell phone may take an hour to charge when plugged into a wall socket, but depending on the charger's output, two to four hours with a portable

PV. And keep your eye on the sun when you're charging—the angle of the sun's rays also affects charging times, so be sure to take the sun's position into account.

Check the device's voltage requirements: Some portable chargers automatically regulate their output to match the requirements of the device they're charging, but others may need additional regulation. Most portable charging devices output only one nominal voltage, but some can be set to charge at more than one voltage. When considering charge voltages, a few tenths of a volt won't matter—from 4.3 to 5, for example—but charging a 4.3-volt digital camera using a 7-volt power source may damage the camera.

Finally, make sure to guard against reverse current. In low- or no-light conditions, devices with built-in blocking diodes prevent the backflow of energy from your battery into your portable PV charger, which in low-light conditions will have a lower voltage than a fully charged battery. Diodes are built into most PVs used for portable charging, but you should always check your charger's documentation before leaving your electronics plugged in for an extended period.

SOLARIS FOLDABLE SOLAR CHARGERS

(www.brunton.com, \$129–\$359)

If you're itching to power larger devices, go for the Solaris 12 or 26, which offers 12- and 26-watt outputs, respectively. Like their smaller counterpart, these larger arrays can charge small handheld devices, but they can also recharge 12-volt laptop computer batteries in a matter of hours, or even charge a discharged car battery after two to four days of full sun.

Each model is water resistant and can be interconnected with identical PV modules to increase total output. You'll need vehicle adapters for charging handheld devices; optional adapters are available for charging AA, AAA, and car batteries. All models include a reverse-flow blocking diode, so you don't have to worry about draining your battery after the sun goes down. Amount of time to charge a cell phone: Solaris 6, 1 to 3 hours; the Solaris 12 and Solaris 26, 1 hour or less.





BRUNTON SOLARROLL (www.brunton.com, \$279–\$399)

POWERFILM R-SERIES ROLLABLE SOLAR-ELECTRIC ARRAYS

(www.powerfilmsolar.com, \$109–\$379)

These waterproof, roll-up PVs are ideal for sea kayakers, river rafters, and techno-heads who can't leave their work behind. They are available in several sizes: Brunton offers 9- and 14-watt models; PowerFilm produces rollables in 5-, 10- and 20-watt sizes. PowerFilm's 5-watt model, the smallest, weighs just under 10 ounces. Brunton's 14-watt unit weighs just 17 ounces and can be rolled into a 3.5-inch-diameter cylinder. The smaller rolls can power handheld devices; the larger ones can charge laptops in a few hours.

As with folding PVs, rollable models can be combined with other units of the same type for higher output—Brunton's SolarRolls come with a cable to daisy-chain multiple modules into arrays; PowerFilm offers the cable as an optional accessory. All of the rollable models include reverse-current protection, as well as adapter cords. Amount of time to charge a cell phone: PowerFilm R15-300 (5 watt) and SolarRoll 9, 1 to 2 hours; PowerFilm R15-1200 (20 watt) and SolarRoll 14, 1 hour or less.



VOLTAIC SOLAR BAGS

(www.voltaicsystems.com, \$239)

REWARE JUICE BAGS

(www.rewarestore.com \$210–\$275)

BACKPACK OR MESSENGER BAGS WITH PV MODULES

Voltaic and Reware both manufacture backpacks with built-in PVs, and each brand has its advantages. Both models provide only enough energy for small devices—they're not powerful enough to recharge your laptop while you're toting it around town. The Voltaic solar bag, available as a backpack or shoulder bag, generates 4 watts with its three interconnected solar-electric modules. A built-in battery pack (2,000 milliamp-hours at 7.2 VDC) stores energy generated while you're in the sun. Both models use a standard DC adapter socket, but the Voltaic model also comes with adapters for ten popular cell phone models, as well as a USB adapter.

Although Reware's Juice bags don't come with battery packs or multiple adapters, you can buy these accessories separately. Reware designs offer a few different features. Their solar-electric modules are removable for remote use, and the higher wattage array recharges electronics faster. The Voltaic bag will charge a cell phone in 4 to 6 hours, while the Reware bags will charge it in 2 to 4. An additional eco-friendly bonus: The Juice bags are manufactured from recycled plastic bottles. According to the manufacturer, each bag saves eight 2-liter bottles from ending up in landfills.



SOLIO HANDHELD PV CHARGER WITH BATTERY PACK (www.solio.com, \$99.95)

Here's how to win over teens whose MP3 player headphones are permanently implanted in their ears: hand them a Solio. It's the size of a cell phone, fits in your pocket, and its three sections fan out to reveal three PV modules. The Solio's average output is 5.5 watts in full sun, enough for small devices. Solio includes an onboard 3.6-volt, 1,600 milliamp-hour lithium ion rechargeable battery pack. This battery type allows the device to maintain its charge for up to a year, so once it's fully charged, it's ready for use when needed. The Solio can be used to either recharge or directly power your portable devices. The suction cup provided can be threaded through the Solio's axis, which allows you to stick it to a sunny window—and charge on the go. Several types of adapters are available to match your specific electronics. The optional 12-volt car adapter (\$11.95) is your best bet, especially if you already own car chargers for your electronic gear. Amount of time to charge a cell phone: 2 hours.



SOLLIGHT LIGHTCAP PV LANTERN/WATER BOTTLE

(www.sollight.com, \$24.95)

Backpackers will delight in this brilliant concept: A water bottle that doubles as a lantern. It looks like any other wide-mouth polycarbonate bottle, but a PV module in its cap charges batteries for two selectable LED bulbs: white for bright light, and red for low light (and minimal energy use). The lightbulb, batteries, and PV module are all molded into the cap, so there's no need to worry about battery electrolyte mingling with your spring water! Four hours of sunshine provide several hours of light; or switch to the red LED and leave it on all night long.



HUMAN-POWERED OPTIONS

When the only available fuel is elbow grease, human-powered devices offer convenient energy on the go. Using a wind-up or stepping motion, these devices convert muscle action into electricity, which is then stored in a rechargeable battery for later use. Traditionally, human-powered electricity has been used in emergency situations, but its convenience makes it attractive for everyday use: It makes recharging batteries a quick process and human power is readily available at the moment you need it. The only limit is your own stamina!

FREEPLAY XRAY CRANK-OPERATED LED FLASHLIGHT

(www.freeplayenergy.com, \$34.99)

The quintessential entry point for portable, sustainable, and pollution-free energy—your own. This model, with its efficient LED bulb, gives 20 minutes of light after a 30-second crank.





FOREVER FLASHLIGHT III

(www.foreverflashlights.com, \$29.95)

The Forever Flashlight is a great lesson in the magic of physics: Shake it vigorously to make the copper-wire coil inside shift back and forth along the column of the flashlight's body. After 10 to 15 seconds, your effort will be rewarded with 5 minutes of light from a bright LED. The secret is Faraday's theory of electromagnetic induction: A magnet passing the copper coil generates an electrical current to power the LED.



FREECHARGE WEZA STEP-ACTION PORTABLE ENERGY SOURCE

(www.freeplayenergy.com, \$269.99)

Originally designed for recharging dead boat batteries, the step-action Weza—which means “power” in Swahili—is now used to charge everything from cell phones to car batteries. It's especially popular in Africa, where grid power is spotty, or often nonexistent.

Pumping the Weza's treadle charges its lead-acid gel-cell battery, and produces between 25 and 40 watts, depending on how vigorously you step! The Weza recharges small electronics through a 12-volt cigarette lighter adapter, and comes with jumper cables for car batteries. A cell phone can be recharged with 5 minutes of step action. It's good for emergency situations of all types—but at nearly 18 pounds, it's not a viable solution for backpackers, hikers, and others who are trying to pack lightly. The downside? Step action is not an effective way to recharge a laptop—5 minutes of stepping (which is quite a workout), equals about 2.5 minutes of run time—not a great payoff for your sweat equity.



ETON FR300 CELL PHONE CHARGER/RADIO

(www.etoncorp.com, \$50)

Although it may look like a humble analog radio, Eton's FR300 is actually a high-tech multitasker. Its wind-up energy powers an AM/FM/shortwave radio, a bright white LED flashlight or blinking red signal LED, and best of all, most cell phones (check their list of supported phones before buying). The FR300 comes with an adapter cable and several cell phone adapters, so you can charge your phone's battery anytime and anywhere.



FREEPLAY SUMMIT WINDUP/PV/DC RADIO

(www.freeplayenergy.com, \$89.99)

Disasters do happen, so whether you're into RE or not, think about owning one of these, because crank-operated radios are perfect for getting news when the power's out. A world-band radio allows you to monitor goings-on around the globe. Thirty seconds of winding provides 30 minutes of radio play, and PV modules on the back of the radio allow for solar (and pollution-free) charging. And if you're impatient, or if 30 seconds of cranking is just too much effort, you can also plug it into a wall socket. But where's the fun—or sun—in that?

Access

Erin Moore Bean • erinmoorebean@gmail.com





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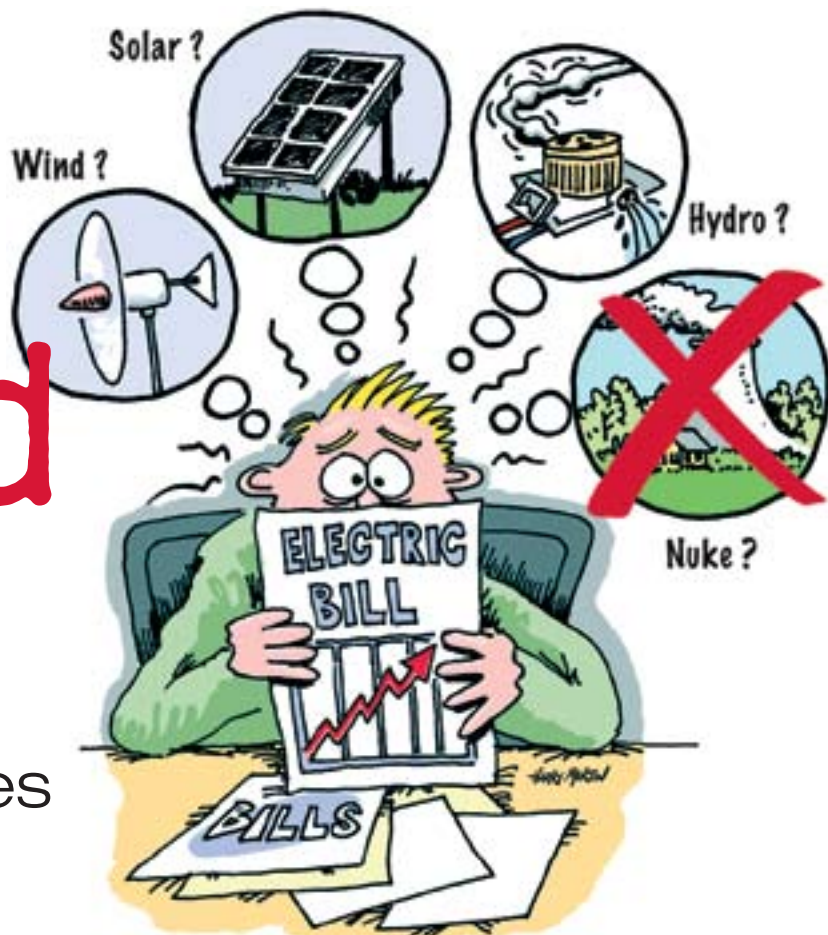


Prepaid Power

Putting Renewables to Work for You

Dan Casale

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For most of us, like death and taxes, purchasing electricity for the rest of our years is an inescapable consequence of powering our modern lives. But what if you could lock in your rate—and eventually produce your home’s energy for free? You also may be able to increase your home’s value, and take advantage of utility rebates, tax incentives, and the immeasurably good feeling of investing in clean, green energy for this and future generations.

All this can come from installing a renewable energy (RE) system at your home. Here’s how you can make the best choices to put renewable energy to work for you.

Meeting Your Needs

The average American household uses about 900 kilowatt-hours (KWH) of electricity each month. But basing system costs solely on that number would most likely give you an inaccurate and unhelpful result. Your electrical use may vary wildly, depending on your habits, what kind of appliances you have, and the time of year.

So how can you gauge your electrical appetite? For a quick snapshot of your electrical usage, check out your monthly electricity bill. Most bills include KWH usage figures for the last twelve months; this will give you a good idea of how much electricity your home uses each year.

Next, take steps to improve your home’s efficiency. Every dollar you spend on making your home more efficient can decrease the cost of a solar-electric system by approximately \$3

to \$5. For example, just replacing an older model refrigerator with a modern, more efficient one could reduce your electrical usage by 50 KWH per month—shrinking the size of the RE system you’ll need. Combine efficiency measures with household-wide conservation strategies and you can make a pretty sizeable dent in your system costs.

Your Options

For electricity generation, your most viable, affordable options for renewable energy include tapping the water, sun, and wind. Microhydro is considered by many to be the holy grail of renewable energy sources. While solar- and wind-electric systems produce variable amounts of energy depending on whether the sun is shining or the wind is blowing, microhydro turbines generate electricity as long as the water is running.

If your site has a creek that drops along its course, microhydro can be one of the most cost-effective options. The first step in assessing the feasibility of any microhydro-electric system is to measure stream flow and head (vertical drop). The water pressure created by the difference in elevation along your pipeline spins your water turbine and generates electricity. Once you’ve assessed your site’s potential, you’ll have enough information to begin the next step—talking with turbine suppliers about design strategies. (For details on microhydro systems, including how to measure flow and head, see “Intro to Hydropower, Part 1 & 2” in HP103 & HP104.)

But most of us aren't lucky enough to have a stream running through our property and can rule out using microhydro systems. So that leaves wind and solar electricity (photovoltaics; PV)—is one better than the other? As with everything, that depends on your location and resources.

Who's Right for Wind?

The economics of a wind system rely largely on a location's average wind speed and the local cost of electricity. According to the American Wind Energy Association, those contemplating wind energy should have at least a 10 mph average wind speed at their sites and pay at least \$0.10 per KWH for electricity. If your place is off-grid, a wind turbine can make sense even in areas with low average wind speeds. Solar and wind energy nicely complement one another, since storm fronts that obscure the sun typically have strong winds attached, making a hybrid PV-wind system a great approach for year-round energy production.

Wind behavior varies radically depending on the location. Just because your neighbor may live on a windy site does not guarantee that your site will have that same resource. Wind data maps can help you identify the general wind speeds and overall patterns in your region, but will not tell you much about a specific site. In most cases, you'll need to rely on an experienced installer to evaluate your particular site's wind potential.

Residential-scale wind turbines measure 8 to 30 feet (or more) in rotor diameter, and should be mounted on 60 to 160 foot towers. Wind-electric systems are difficult to install on city lots or small lots in the suburbs, largely because of space limitations and tower height regulations. Wherever you install a wind turbine, to maximize your system's effectiveness, site it on a tower well above all nearby obstructions.



**Instead of grumbling about the wind,
make electricity every time it blows.**

With their many moving parts, wind generators require routine maintenance—at least annually. This requires climbing or lowering the tower to service the turbine. Wind-electric systems will always be less reliable and require more maintenance than solar-electric systems. They are not for the fainthearted!

Several states offer rebates to help offset the up-front cost of a wind-energy system. Presently, these cash-back incentives reward system owners by reimbursing them for up to 60 percent of system costs.

Off Grid...Or On?

You may fantasize about going off the grid—disconnecting from the electrical utility completely and asserting your energy independence. And while thumbing your nose at the utility monopolies may have great appeal, if you're planning to install an RE system, and if you already have utility electricity at your site, it makes sense to tie your system to the grid, rather than cutting the cord. The primary reason for this has to do with energy production losses when off-grid systems are regulating. In off-grid systems, once the batteries are full, a controller throttles back the output of the RE sources to keep the batteries from being overcharged. Additionally, the battery charge-discharge cycle can consume up to 20 percent of your energy. If the same system is grid-tied, any excess energy gets exported back to the grid, which significantly increases the annual production of your system and puts those otherwise uncaptured electrons to use.

Off-grid systems are usually cost effective compared to a utility line extension of 1/4 mile or more. While living off-grid might be the biggest statement you can make when it comes to being independent, it also requires homeowners to

actively manage their energy use to avoid overly depleting (and damaging) their batteries. The most commonly used batteries (flooded, lead-acid) require routine maintenance. During inclement weather, many off-grid systems also need an occasional boost of energy from fossil-fuel engine generators, which can be noisy and polluting nuisances.

On-grid batteryless systems have the advantage of being easily scalable to fit your budget—you can offset as little or as much of your household energy use as you can afford. Plus, these systems are virtually maintenance free and won't suffer from the energy-unwise choices of unwitting household members—Pat can still run the electric hair dryer and blast the boom box, while Marti tinkers in the woodshop, Shawn bakes a turkey in the electric convection oven, and Chris plays video poker on the computer. The downside? If your system is batteryless, when the grid goes down, so does your system. If you have frequent utility outages at your location, consider a grid-tied system with battery backup. These systems will allow you to power priority loads like lighting, communications, refrigeration, and water pumping when the grid goes down.



A solar-electric system can turn your home's rooftop into a power plant—no noise, no worries.

Using the Sun

With no moving parts, solar-electric (photovoltaic; PV) systems are durable, quiet, reliable, and virtually maintenance free. Several Internet sites can provide accurate estimates of the amount of sunshine (peak sun-hours) you can expect to harvest on a daily, monthly, and yearly basis (see Access). Less sunny locales call for larger systems to generate the same amount of electricity that a smaller system in a sunnier spot can produce. Knowing the seasonal minimums and maximums for your area can help you understand the potential for PV at your site. Successful solar-electric systems have been installed

and produce electricity in all areas of the country—from the northern reaches of Washington State to the Sun Belt.

But even the sunniest regions won't guarantee you good system performance unless you have unobstructed solar access at your site. This daily access to the sun is called your "solar window." You'll need a location on your rooftop or elsewhere on your property that:

- Ideally faces south, though east- or west-facing arrays can be surprisingly productive, so don't rule them out if they are your only options.
- Provides enough space for the number of PV modules needed, possibly including room for future expansion.
- Enables the entire array of modules to have unshaded exposure to the sun during peak sun-hours.

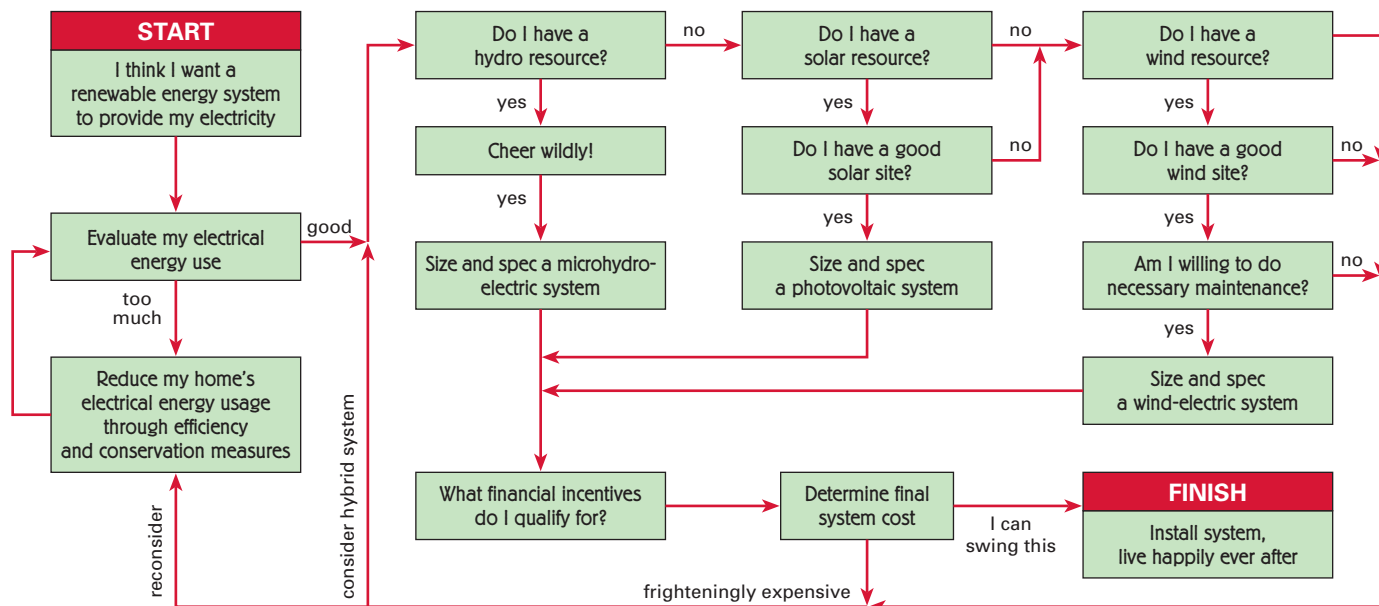
If you want to assess your site's resource yourself, consider using the Solar Pathfinder to help you determine the best place to site your system (see Access).

One of the best features of solar electricity is its scalability. With a little foresight, you can start small and build your system gradually if that better suits your budget. A starter system can be designed to meet any portion of your home's daily electricity needs. This is one great benefit of a grid-tied system—the remainder of your electricity can be purchased from your electric utility, just as before. And, if you plan your system for future expansion, adding more modules to your array as your pocketbook allows is relatively simple.

To maximize the energy produced by your investment and to minimize PV system costs, always look for the sunniest location on your property to install your array. Don't assume that the roof is your only option: Pole mounts, wall mounts, and ground mounts are worth considering too.

While it is common practice to mount PV arrays on a home's roof, assess your roof's condition—and remaining life span—before doing so. Putting a new array on an old roof

Finding Your Renewable Energy Path



Going Solar—The Author's Solution

After implementing many common energy efficiency measures like swapping out incandescent lightbulbs for compact fluorescents, installing an automatic setback thermostat, and purchasing more energy efficient appliances, I deemed my household ready for renewables. My wife Capa and I live in the Nevada desert, where few flowing streams exist to make microhydro viable, and the valley bottom where we live barely qualifies as a Class 2 (average wind speed of 10 mph) wind zone. But, with almost 300 sunny days each year, PV is a perfect match. Since PV array output increases as temperature decreases, our cold, sunny winters also boost our PV system's annual production by about 10 percent.

A quick check of a year's worth of electricity bills showed that our household consumed about 600 KWH per month. With more than 5 average daily peak sun-hours at our site, we needed at least a 5 KW PV system to meet these needs. Most grid-tied inverter manufacturers have a sizing tool that will assist you in sizing your system—or if you don't want to or are unqualified to do it yourself, hire a PV pro to size, design, and install your system.

Our system finally came online at the end of June 2005. Toward the end of July, the first electricity bill arrived—with a charge of only \$4.12, the utility connection fee. Three months later, we had accumulated an excess of 1,500 KWH. A quick trip to a hardware store netted three electric heaters and a plan to offset some of our natural gas usage with solar-produced electric heat. After two months of assisting the gas-fueled furnace with electric heat, we had consumed about half of the excess KWH and made a noticeable dent in our natural gas consumption.

At our present electricity rate, without factoring in any federal or utility incentives, our solar-electric system will have recovered its initial cost in 33 years. However, if we account for the available

For author Dan Casale and his wife Capa solar energy was the most abundant renewable resource at their site, and photovoltaics were the solution.



incentives, the payback time shrinks to about 18 years, well inside the PV modules' warranty period. If installed as part of a business venture, business tax incentives further reduce the payback time to about eight years. Federal and, in some cases, state tax credits are also available for homeowners who have PV systems installed.

Since we've installed the system, local utility rates have gone up twice, the utility PV rebate has gone down twice, and both the federal personal and business rebates look great. So don't delay—get your plan together to "prepay" your electricity bill.

Tech Specs

Overview

System type: Batteryless, grid-tie PV

Location: Sparks, Nevada

Solar resource: 5.8 average daily peak sun-hours

Production: 1,055 AC KWH per month (average)

Utility electricity offset: 100 percent

Photovoltaics

Modules: 32, Kyocera KC187G, 187 W STC, 26.1 Vmp

Array: Two 16-module series strings, 2,992 W STC each, 418 Vmp, 5,984 W STC total

Array installation: Adjustable UniRac mounts with high-profile legs, ground-mounted on a concrete slab, 30- to 60-degree tilt angle

Balance of System

Inverters: Two Xantrex GT3.0, 3,000 Wp, 195–550 VDC MPPT range, 240 VAC output

System performance metering: Built-in inverter displays and utility-supplied KWH meter

System Economics

Item	Cost
Initial cost	\$52,689
Green energy credits sold	-25,000
Tax credits & deductions (over 5 yrs.)	-16,000
Total Cost	\$11,689
Payback Period (Yrs.)	7.2
Annual Electricity Savings	\$1,519
Annual Gas Savings (Electric Heating)	\$105

will inevitably result in the added expense of dismantling and moving the array when you have to replace the roof. If a new roof is already in the plan, you may want to consider building-integrated PV (BIPV) materials, like PV laminates, which adhere to standing-seam metal roofs, or solar-electric shingles, tiles, or other roof-integrated systems (see "Install a Solar-Electric Roof," in *HP114*). A potential drawback of thin-film BIPV technologies is that they are about half as efficient as crystalline modules. Since the fuel (sunshine) is free, the bottom line is simply that this material requires more roof space, so make sure you have it.

If your roof is not ideal for PV, consider a pole- or ground-mounted array. They can offer the benefit of being easier to adjust seasonally for maximal production (no climbing on roofs!), and they are easier to clean if dust or snow builds up. Pole-mounted arrays can be fitted with a tracker that keeps the modules facing the sun throughout the day, increasing the annual output of the system up to about 30 percent.

Currently, most financial incentives for grid-tied PV systems are based on installed watts—and that makes adding panels more cost effective than installing trackers. But in places where incentives are based on power production rather than installed watts, the benefits of increased PV production may outweigh the cost of purchasing tracking mounts.

Free Money

Perhaps the most powerful impetus behind the exploding popularity of residential-scale grid-tied RE systems is the

availability of generous financial incentives—including federal and state tax credits, and cash-back rebates. For tax years 2006 and 2007, you can deduct up to 30 percent (\$2,000 maximum) of your home's solar-electric system costs from the bottom line of your federal tax return, and carry any excess credit to the next tax year.

In some states, rebate programs refund as much as 60 percent of a solar-electric system's installed cost to the homeowner. Add to that tax credits and exemptions, and low-interest state loans, and the picture gets brighter still. You can get up-to-date information on financial incentives at the Database of State Incentives for Renewable Energy Web site (see Access). Check it out and get started. The decisions you make today can turn into energy tomorrow.

Access

Dan Casale • www.groups.yahoo.com/group/alternatpower/ • dan_casale@nshe.nevada.edu

Renewable Resources Data Center • <http://rredc.nrel.gov/solar/pubs/redbook> • Maps, charts, etc.

Residential RE Rebate and Incentives Information • www.dsireusa.org

PV System Sizing (Solar) Estimator • www.findsolar.com

Solar Pathfinder • 317-501-2529 • www.solarpathfinder.com • Solar site assessment tool



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ANATOMY OF A

Ian Woofenden & Hugh Piggott

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For thousands of years, people have been harnessing the energy of the wind. A fascination for wind energy has driven both of us to build, buy, install, and maintain our own machines for the last three decades. Chances are that the first wind-energy users were driven by the same maniacal glee that we experience when we grab energy out of thin air.

The design of home-scale wind-electric generators has been through many permutations and variations, with lots of circles and dead ends. But most of today's modern wind-electric generators are surprisingly similar. This article will help you understand each part of a typical wind generator, and how it functions in the overall design.

Tail Boom & Vane

Turns wind turbine to face the wind

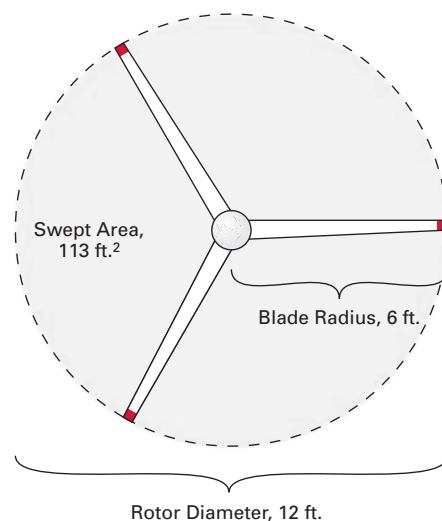
ROTOR (BLADES & HUB)

"Rotor" is just a fancy word for a wind turbine's blade assembly—the part that rotates. (There are actually two rotors—the blade rotor, and the magnet rotor in the alternator or generator, which is driven by the blade rotor.) The wind generator's blades are the energy collectors. After the wind itself, the circular area that the rotor sweeps is the most important factor in determining how much power the machine can generate. The swept area of the rotor depends on the square of the diameter. Compared to a 5-foot-diameter rotor, a 10-foot one will be twice as wide, and twice as high. Doubling the diameter gives access to four times as much wind, and usually results in four times as much power.

Most modern wind turbines have three blades. Blades are usually made of plastic, often in a composite with fiberglass, or sometimes out of wood. Rotors with more than three blades have more start-up torque, but actually produce less power at high speeds. Two-bladed rotors can work at even higher speeds than their three-bladed counterparts, but can be noisy and also vibrate when the wind changes.

Mechanical power is a combination of speed and torque. Wind-electric generators need to spin at relatively high rpm and at low torque, unlike water-pumping wind machines, which need low rpm and high torque.

For home-scale wind generators, the blade rotor drives the magnet rotor directly. This design is the simplest and most efficient way to collect the wind's energy. Adding belts, pulleys, gearing, or any other indirect transmission will incur losses, as well as require more maintenance.



A cross-section of an extruded carbon-fiber blade shows the airfoil shape.



Courtesy www.bergey.com

WIND TURBINE

Rotor, stator, diode rectifier, slip rings, and bearings exposed on a Bergey XL.1 1 KW generator.



Courtesy www.bergey.com

Governing System

Offset mounting of turbine on its yaw bearing causes turbine to yaw out of the wind rather than overspeed

Alternator Stator:
Electrical current is induced in the copper windings by the electromagnetic field from the rotating magnets

Blades:

Blade airfoil needs to have good lift/drag ratio to rotate at speeds faster than the wind

Alternator

Alternator Bearings and Front Plate not shown

Nose Cone:

Provides visual appeal and some protection for alternator

Shaft

Alternator Rotor:
Permanent magnets rotate past stationary windings in the stator, inducing electrical current

Rotor

Brushes & Slip Rings

Transmit electricity through the rotating yaw bearing

Yaw Bearing

Permits the turbine to rotate to face the wind

Transmission Wires

Stub Tower:
Attaches turbine assembly to tower top

ALTERNATOR

Most modern small-scale wind turbines employ permanent magnet alternators (PMAs). Electricity is generated when a magnetic field passes a wire. In a PMA, magnets move relative to coils of wire (windings). In one popular configuration (as shown in the diagram above), the magnet rotor is a rotating "can" that spins outside the coils. The magnets are on the inside (facing the coils) and the blades attach directly to the front of the can. These PMAs usually generate wild three-phase AC, which is not usable by appliances directly. Instead, this energy is rectified (converted to DC electricity). After that, it can be used as DC or inverted to AC electricity for AC appliances. Traditionally, the energy has been stored in batteries, but in many modern wind-electric systems, it is fed straight into the household grid supply.

The stator from a 10 KW Bergey Excel showing multiple windings. A bearing in the center supports the rotor.



Courtesy www.bergey.com

TAIL BOOM & VANE

The tail of a wind generator orients the turbine into the wind. When the wind changes direction, it pushes on one side of the tail, swinging the turbine around to face and collect wind energy. In tail-furling designs, the tail is also involved in protecting the turbine from high winds (see Governing Systems), and tail and boom length are designed carefully for weight and area. Changing these parameters can change the way the machine operates—so don't do it.

SHAFT & BEARINGS

The shaft of a wind turbine carries both rotors—the blades and the rotating part of the alternator. The shaft is suspended in bearings, which are usually sealed permanently. They need to be designed to withstand all the stresses of supporting the blade hub and any vibration from the alternator. Bearings typically last five to ten years.

SLIP RINGS & BRUSHES

Wind generators yaw to face the wind, but the transmission wiring is fixed to the ground. This can be a recipe for twisted wires, especially at turbulent sites where the yaw bearing is very free-moving. Most modern turbines use copper alloy slip rings to connect the turbine wiring to the fixed wiring. The slip rings are usually mounted in the part of the turbine that is fixed to the tower top. A set of graphite brushes is mounted on the yawing part of the turbine. The brushes ride on the rings as the turbine yaws, and serve to connect the alternator to the fixed wiring.



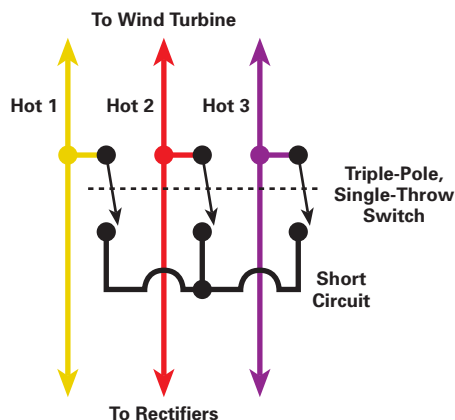
YAW BEARING

A wind turbine needs to be able to follow the wind, changing orientation each time the wind changes direction. The sealed bearing that supports the wind turbine as it swivels on its tower is called the yaw bearing, and the swiveling motion is called yawing.

Slip rings and brushes, and yaw bearing assembly from an ARE wind turbine.

BRAKING SYSTEM

Braking, as distinct from governing, is the ability to stop the turbine when you choose to. This can be useful when there is a problem with the machine, when you need to work on it, or when you simply don't need the energy. Manual braking is ideal, since it allows you to stop the machine in all conditions. Drum and disc brakes have been used in a few turbine designs, but most turbines use dynamic, or electrical, braking, where a big switch opens the connection to the grid or batteries, and shorts the three phases of the wind turbine together, making it very stiff to turn. Many wind turbines cannot be slowed by a short circuit once they are already running fast in high-wind conditions. Another method of control is manual furling—the ability to manually crank the tail over to furl the machine out of the wind.



ENERGY TRANSMISSION

Wiring routed down the tower carries the electricity generated by the turbine to the control room, usually as wild (varying voltage) three-phase AC. A few turbines rectify the output at the tower top, and transmit it as DC. Using thick copper wire reduces the risk of fire and limits power lost as heat. Where the wire run is very long, high-voltage AC transmission to a step-down transformer at the control room can be used to save on wire cost and energy losses. Batteryless grid-tied inverters work with higher voltages than most battery-based systems, so they lose less energy in transmission.

One feature of Southwest Windpower's controller is to rectify the turbine's AC output to DC for battery charging.



Courtesy www.windenergy.com

NACELLE

Some wind turbines use a plastic cover (cowling) spaced away from the alternator, which protects it from rain but allows airflow over the alternator for cooling. Many turbines have a separate nose cone, which serves an aesthetic purpose, as well as streamlines the turbine.

GOVERNING SYSTEMS

To a novice, high winds seem like a bonus. But to seasoned wind-energy users and turbine designers, once the wind turbine is already going flat out, stronger winds become a cause for concern. Doubling the wind speed makes *eight times* as much power available, and also increases the thrust force on the turbine and tower by a factor of four.

A turbine should be able to shed excess force, or it will overspeed, burn out, or self-destruct in some way. Protection from strong winds, called governing,

can be accomplished either by furling or by blade pitch-control. The most common governing system is a furling tail that steers the rotor out of the wind. Some machines twist the angle (pitch) of their blades toward stalling, which decreases their efficiency and prevents overload. Both of these systems are passive, in the sense that they are driven by the force of the wind, or by the speed of the blade rotor. Very recently, electrical braking also has been introduced to automatically control a turbine's speed.

As the wind approaches this turbine's rated speed for maximum power, the rotor begins to swivel out of the wind to prevent overspeed.



Putting It All Together

In an effective wind generator design, all of these systems and components are carefully matched to each other. For example, the alternator must produce power at the best rotational speed (rpm) to get the most power from the blade rotor. Too slow and the rotor will stall; too fast and the machine will be noisy and ineffectual in low-speed winds.

Of course, a complete wind-electric system is much more than just the turbine. Other major components are the tower, rectifier, charge controller and dump load, battery bank (if needed), inverter, and metering. Several of these components can be more expensive than the turbine, and all of them need to be considered as you design a complete system.

The bottom line is to buy a turbine that is robust, simple, low speed, and reliable. Talk with experienced wind-energy users to find out which turbines stand the test of time. Heavier wind turbines with larger swept areas are usually more expensive, but more durable.

Focus on the energy the turbine makes, not its peak power. The energy will depend on the swept area and the average wind speed at the tower top. A small rotor on a short tower will not generate much energy. Remember that low and medium wind speeds are the most frequent, and therefore the most important. Do it right and you can share our glee in wind energy.

Access

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DC Power Systems • 800-967-6917 • www.dcpower-systems.com

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Southwest Windpower • 866-807-9463 • www.windenergy.com

Wind Turbine Industries Corp. • 952-447-6064 • www.windturbine.net

Additional Reading:

"Apples & Oranges: Choosing a Home-Sized Wind Generator," by Mick Sagrillo in *HP90*

"Wind Generator Tower Basics," by Ian Woofenden in *HP105*

"Wind-Electric Systems, Simplified," by Ian Woofenden in *HP110*

Wind Power: Renewable Energy for Home, Farm, and Business, by Paul Gipe, 2004, Paperback, 496 pages, ISBN 1-931498-14-1, \$50 from Chelsea Green Publishing Co. • 800-639-4099 or 802-295-6300 • www.chelseagreen.com



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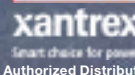
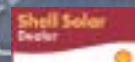
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MAPPING

Energy Needs with Renewable Energy Resources

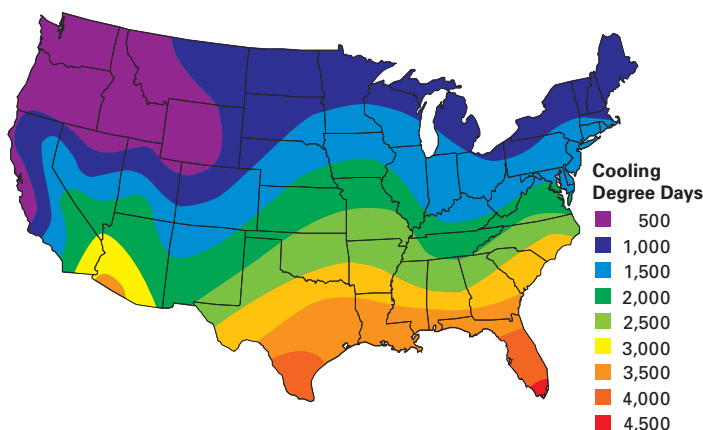
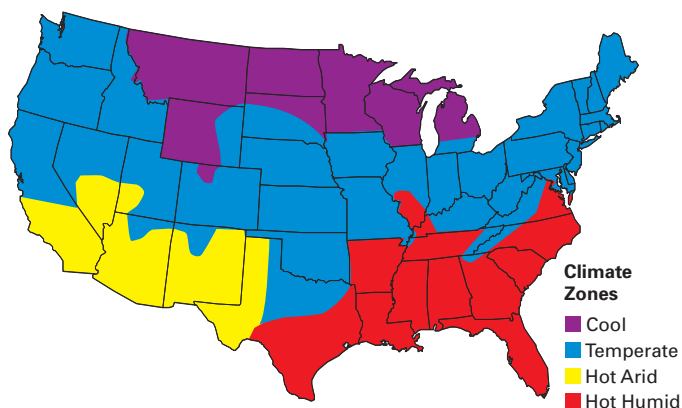
Moving forward, renewable energy (RE) resources could provide most of the energy America needs while being cleaner, safer, healthier, and cheaper than coal or nuclear energy.

It's important to have a clear picture of both our nation's complex energy needs and what resources are available to make intelligent choices for the future. The maps on these pages show the various climatic regions of

the United States, locations that have similar cooling and heating requirements, and the wide range of renewable resources available to satisfy our energy needs, whether it's for cooling, space or water heating, or electricity. At home, use the maps shown here to plan your own big picture renewable energy strategy. Then conduct a specific survey of your site to identify what renewable energy options will be most productive for you.

Climate Zones

This map divides the United States into four basic climate zones, based on average yearly temperatures and relative humidity. The extra heat stored in moisture in the air means that homes in the Southeast may rely more on air conditioning to keep cool, while homes in the hot, arid Southwest may be able to use thermal mass and good ventilation to combat excess heat gain. Individual sites vary widely, with microclimates even within one town or county. Getting to know your property's climatic conditions is a first step to designing an energy efficient home that makes the best use of RE resources.



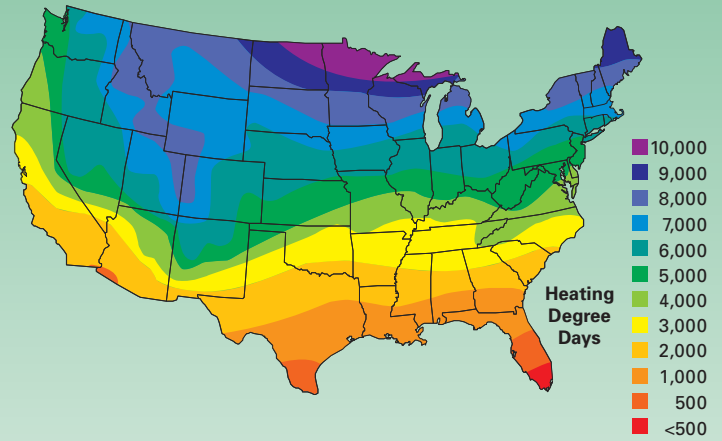
Cooling Degree Days

This map shows cooling degree days, which reflect how hot a climate is and how much energy may be needed for cooling buildings. If you live in the purple zone, your home may not need mechanical cooling, and natural ventilation strategies may be sufficient. If you live in the Southeast's orange or red zones, your air conditioner may be running all day in the summer, and is costing you plenty. Planning your home to include passive cooling strategies can reduce or eliminate the need for energy-intensive air conditioning.

Design roof overhangs properly, use porches to keep the sun off the house, incorporate natural ventilation strategies, and plan your landscaping with cooling in mind.

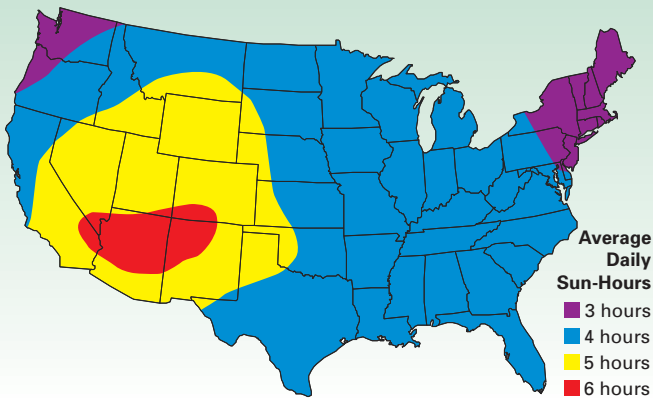
Heating Degree Days

Heating degree days gauge the amount of heating needed for a building, using 65°F as a baseline. If you live in the blue or purple zones, you're probably spending a sizeable chunk of change each year to heat your home. If you live in the orange or red zones, your home rarely needs auxiliary heating and may not even have a heater. In the moderate zone between these extremes, you'll need to heat your house in the colder winter months—and the cost of heating fuels and electricity is going up. The good news? Passive solar design and active solar heating systems can supply some or all of your heating needs in most places in the United States.



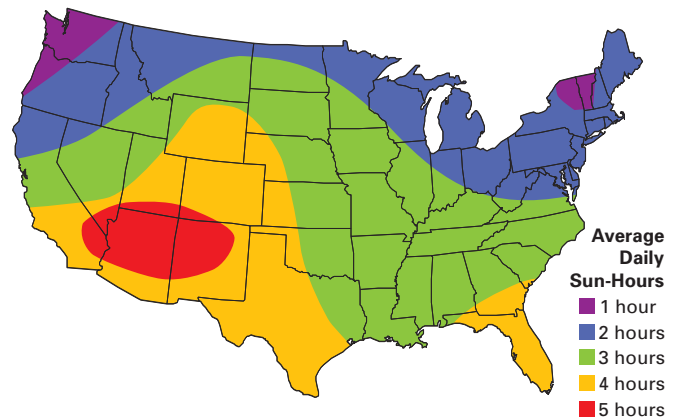
Average Daily Solar Availability

This map shows the average number of peak sun-hours per day on an annual basis, and is useful for considering where solar electricity and solar water heating are most effective. The minimum value of 3 hours per day makes using solar energy feasible anywhere in the United States. Knowing your area's average number of sun-hours is a necessity for designing a solar-electric or solar thermal system that will give you the performance you want.



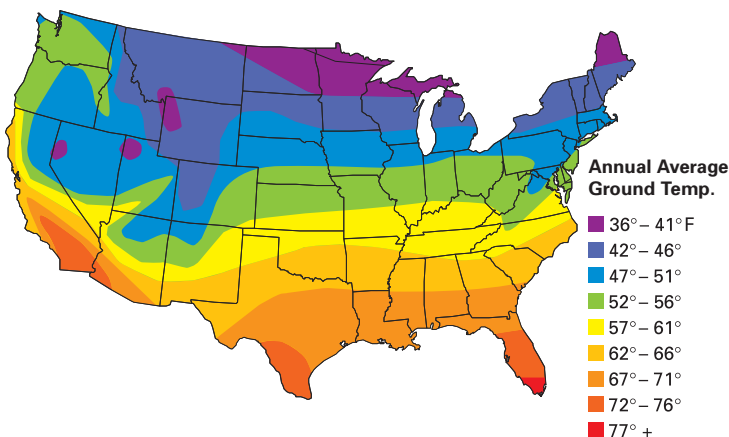
Average Daily Winter Solar Availability

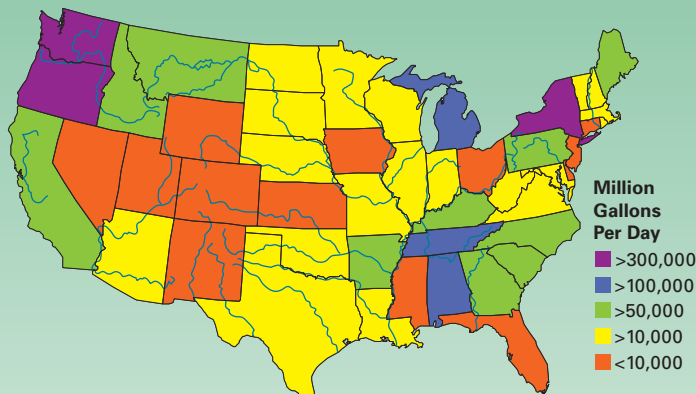
Here you can see the average number of peak sun-hours per day in winter, which will help you determine where active and passive solar home heating are feasible. It will take longer to realize a return on your investment in regions that have only 2 sun-hours per day, and careful design will be necessary to ensure an effective system. The areas with only 1 sun-hour per day (purple) are not as practical for solar heating. All other regions are great candidates for active (with pumps or fans) and passive solar heating systems.



Annual Average Ground Temperature

A heat pump can allow a homeowner to access geothermal energy—the heat stored year-round in the ground. Heat pumps use electricity, but cost about half as much to operate as a natural gas furnace and about a third as much as a propane furnace. Heat pumps are feasible almost anywhere on this map. Colder regions may require burying heat exchanger pipes deeper in the ground or vertically to reach a consistent, warm earth layer. Heat pumps can both heat and cool your home using geothermal heat transfer.



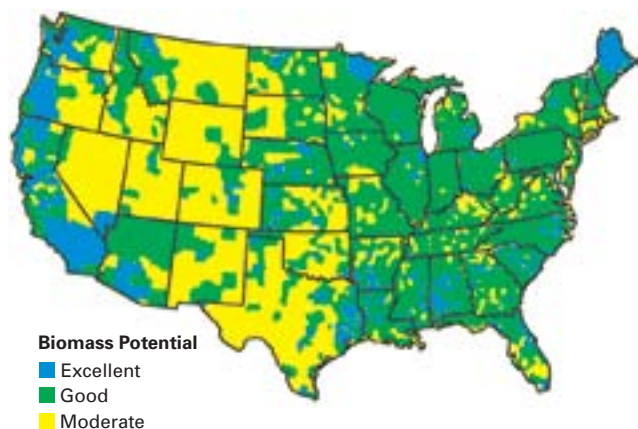
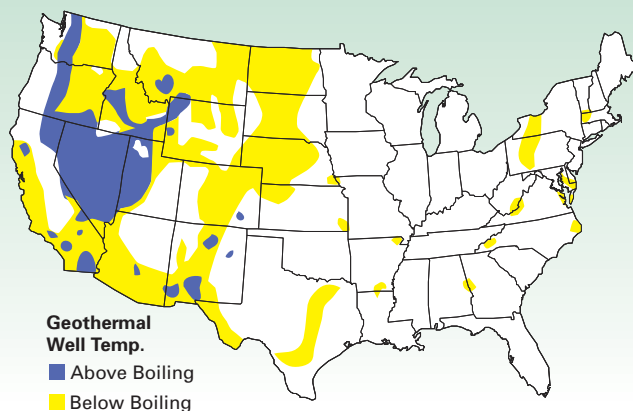


U.S. Hydro-Electric Use

The map shows the use of large-scale hydro-electric resources, and generally indicates the availability of hydro potential by region. Large dams like those found in the Northwest have nearly destroyed some fisheries. We need better ways of implementing large-scale hydro-electric systems to minimize ecological impacts, and well-planned installations of residential-scale microhydro-electric systems. Hydro is one of the most cost-effective ways to generate large amounts of electricity.

Deep Geothermal Resources

Deep geothermal resources are primarily of interest to utilities. The purple areas have temperatures above boiling (greater than 212°F). These are the favored deep geothermal regions because they make extracting energy so easy—insert water and get back high-pressure steam to turn turbines and generate electricity. It is feasible to extract energy in the yellow regions, which generally have geothermal resources with temperatures below the boiling point, but it's less effective and more expensive. The West has far more deep geothermal resources than the East.

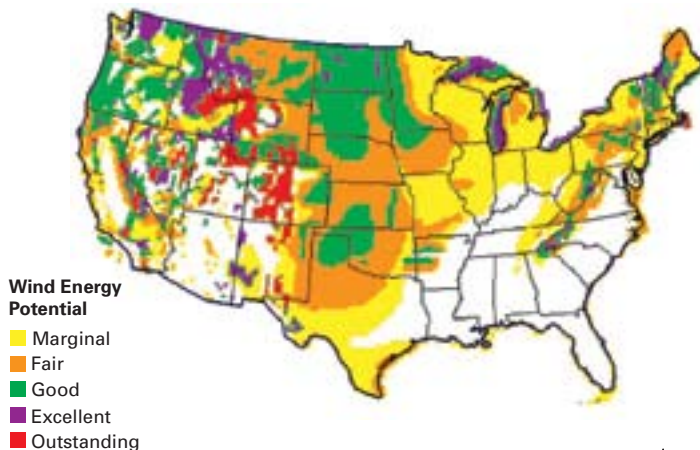


Biomass Potential

Most areas of the country are capable of growing and harvesting vegetation to create fuels such as biodiesel and ethanol. Harvesting from Midwest and California farmlands will yield a better return on investment, but we need the majority of these lands for food production. Biodiesel and E85 (85% ethanol fuel) have the potential to be part of the solution to the problems of petroleum availability, global warming, and ozone layer depletion. And switching from petro- to biofuels will also help cut down on inner city pollution. Efforts to research and develop biofuel resources in the United States have begun, and both biodiesel and E85 retail fueling stations are popping up across the country.

Wind Energy Potential

Many regions of the country have excellent wind energy potential. Last year, utility-scale wind power was the second fastest-growing electricity source in the United States. For those who want to tap wind energy on their property, using local wind data and anemometry are recommended, if available. Knowing the average wind speed at your site will allow you to make a reasonable prediction of wind energy production. A wind-energy expert will be able to provide a more thorough site assessment for your home or business.



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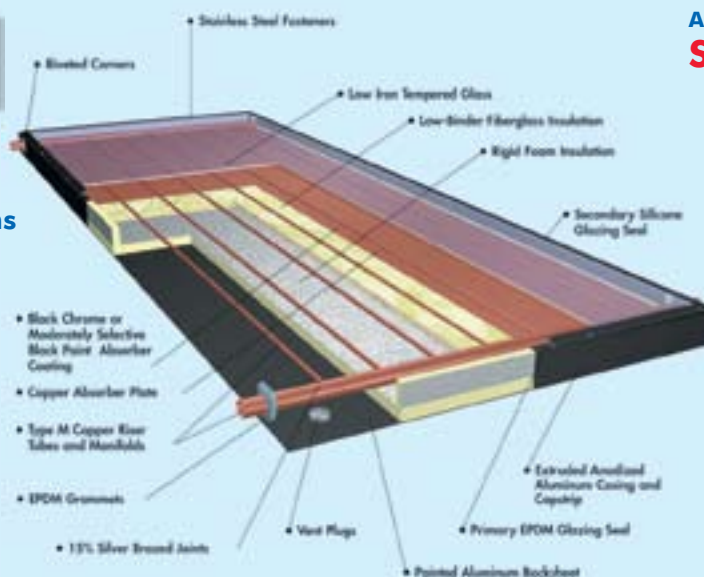
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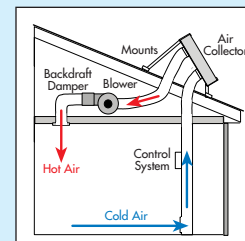
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Passive solar design can make a home more comfortable in every season. The winter sun can warm a home's interior, while simple shading and thermal mass strategies can prevent summer overheating.

The home designs on the following pages balance four primary building elements—orientation, windows, overhangs, and thermal mass—to optimize use of the sun's energy. While these elements are found in most conventional homes, the designs included here put the right amount in the right places for maximal efficiency and performance. Most of them also provide ample south-facing roof space to accommodate the addition of solar hot water collectors and solar-electric arrays—part of a whole-house plan for energy efficiency and independence.

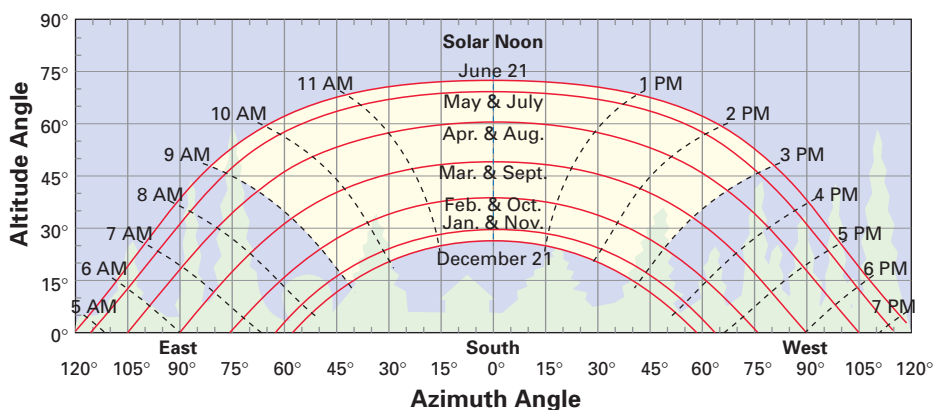
Whether you're having a builder construct your own home from these plans or building for a client, consider these best design bets.

Site Right

In the winter, the sun rises in the southeast, is low in the south sky at midday, and sets in the southwest in the middle latitudes in North America. In the summer, the sun rises in the northeast, is high in the south sky at midday, and sets in the northwest.

In all areas except the southern tip of Florida, choose a home site that receives full southern sun in winter and is unobstructed by trees, other buildings, or hillsides. Besides your own observations about shading during the seasons, site analysis tools can provide a quick, accurate assessment of your proposed building site (see Access). You can also use a compass to help find true north and south, but keep in mind that a compass points to magnetic north, which can vary by as much as 25 degrees from *true* north. This difference is called magnetic declination. You can find the declination of your location by visiting www.ngdc.noaa.gov/seg/geomag/jsp/Declination.jsp.

Sun Path for 40° North Latitude



To maximize winter sun and summer shade, orient the home's south face to within 10 degrees of true south. Even though orienting the house 30 degrees from true south reduces winter solar gain by only 13 percent, the cooling penalty can be greater. Homes facing from 30 to 45 degrees east or west of south may need longer overhangs. This is especially true if the home's orientation favors the west, because overhangs quickly become much less effective as the hot western sun, low in the sky, strikes the house. In most locations, a slight orientation to the east is desirable to increase winter morning sun and decrease summer afternoon sun.

Proper Window Placement

Heat from the sun entering south-facing windows and doors with glass can provide between 20 and 80 percent of the heat required to keep a house warm in winter. The highest percentages are possible in homes in mild climates and those that are well insulated.

South-facing glass should be at least 5 percent and usually no greater than 12 percent of the conditioned square footage of the house. (For example, a 1,000-square-foot house would have between 50 and 120 square feet of south-facing glazing.) Ideally this should apply separately to each floor of the house. Include only the *glazing* square footage—do not include window or door frames. For instance, a 30- by 60-inch window (12.5 square feet) might only have 10 square feet of glazing.

Homes with south glass area between 5 and 7 percent are commonly referred to as sun-tempered, and are appropriate for very hot climates such as the southernmost areas of the United States (as a rule, below 35 degrees north latitude, although there are many exceptions based on local climate conditions). If south glass exceeds 7 percent of the floor area, install materials with high thermal mass inside the house, such as concrete or masonry, to moderate interior temperature swings.

Place just enough windows on the north, east, and west walls to balance interior light levels, capture any views, create an attractive house, and allow for natural cooling. But be sparing, because windows placed in these orientations are energy drains in cold months and, in the summer, eastern and western windows let in unwanted hot morning or afternoon sun, unless they are shaded. For balanced lighting and ventilation, place windows on opposite or at least two sides of each room. Limit the use of skylights, which admit too much sun in the summer and are difficult to shade. Instead, install sun tubes (also known as tubular skylights) in interior rooms without windows, which let in some light, but less heat.

Window manufacturers often use “solar” to describe glazing, but usually this is an indication that the glass *blocks* the sun (has a low solar heat gain coefficient; SHGC) and can be very misleading. For passive solar space heating, south-facing windows should have a high SHGC (at least 0.52) to maximize the amount of the sun's heat that passes through the glass. A window with a SHGC of 0.33 lets in only 33 percent of the sun's heat energy. If you can't find high SHGC windows, a reasonable option is to install clear (uncoated) double-paned glass and use insulated blinds or shutters at night to minimize heat loss. Alternatively, triple-paned clear



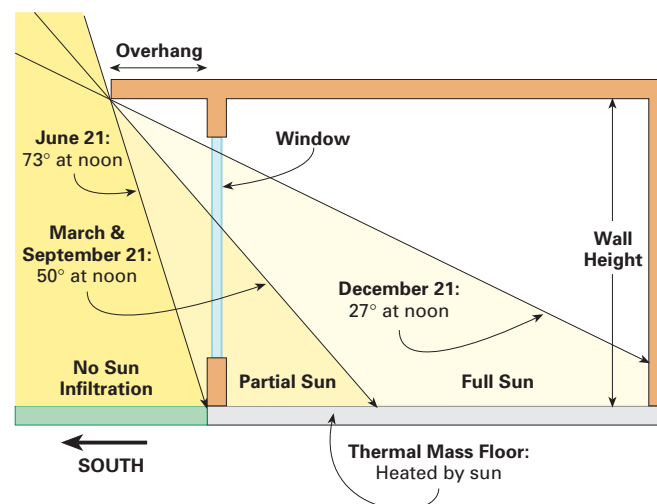
The right amount of glazing, facing the right direction, is only one element of a successful passive solar home design.

glass will let in a large amount of sun while limiting heat loss. Some building codes stipulate a maximum SHGC of 0.4, but then allow you to average all of the SHGCs so that windows with higher SHGCs can be used on the home's south face.

Seek Summertime Shade

Overhangs, awnings, and porches can shade windows in certain seasons and prevent the home from overheating. For cold climates, design overhangs for a long season of full sun striking the south glass. Overhangs should fully shade south-facing windows during the summer months, and allow full sun on windows during the wintertime. For hot climates, design overhangs for a long season of full shade on the south glass. It is fairly simple to achieve full shade on June 21, the summer solstice, when the sun is high. Shading in August becomes more difficult, since increasing the overhang depth will also shade the window in April, when more solar gain may be desirable for heating. This is where a slight easterly rotation of the house can help.

Roof Overhang for 40° North Latitude



South window overhangs should be sized for the height of the windows, wall height, and the construction detail of where the roof meets the wall. West and east windows require much longer overhangs, and these windows are best shaded by other methods, such as porches or trees. Computer simulation software, such as the shareware at Sustainable by Design (www.susdesign.com), and especially the online Overhang Design Tool, can make sizing overhangs a snap if you, your builder, or design professional understand roof/wall construction details.

During the late summer and early fall months, it may be necessary to close blinds or curtains, and pay more attention to passive cooling strategies like opening windows when the temperature drops below 70°F, and closing up the house in the morning, before the day begins to warm. Likewise, in late spring, there may be a few cool days where more heat is desired than is entering the partially shaded south windows. Conserving the heat that does enter by using insulated curtains on the windows can be highly effective.

Make It Massive

Materials with high thermal mass, such as brick, stone, ceramic tile, and concrete, absorb direct solar gain in the winter and indirect heat during the summer. Although it is best to locate thermal mass in the path of direct sunlight, other mass in contact with the material that receives direct solar gain can serve the same function. Including thermal mass is especially important for homes with glass above 7 percent of the home's square footage. Locate the mass as close to south-facing windows as possible. For each square foot of glass above 7 percent, add:

- 5.5 sq. ft. of mass in floors that receive direct sunlight
- 8.3 sq. ft. of mass in walls and ceilings in the same room
- 40 sq. ft. of mass in floors that don't receive direct solar gain

Strive for a minimum of 2 inches (and a maximum of 4 inches) of thermal mass. Less than 2 inches does not store sufficient heat and more than 4 inches (unless it is an 8-inch wall with both sides exposed) can absorb so much heat that



Thermal mass, like this brick wall and floor, stores solar heat and releases it slowly.

Passive Solar House Plans

Although the house plans on following pages were originally designed for clients in specific climates, they are adaptable to other situations. In hot climates, the south glass can be reduced to 7 percent. Occasionally south overhang lengths may need to be slightly shortened or lengthened. Specifications that accompany the blueprint and CAD drawings recommend appropriate insulation values for the slab, basement, walls, roof, and windows, as well as the SHGC for south windows for the climate in which the house is to be constructed.

it will be too slowly released. The maximum amount of floor mass area that should be used is 1.5 times the south-facing window area, since the sun cannot hit large areas all at once.

For cost effectiveness, use concrete, concrete masonry, and earthen plasters as thermal mass. Slab-on-grade construction, where a concrete floor is poured over insulation, can economically combine the foundation with a heat-absorbing floor. ICF (insulating concrete form) foundations, which sandwich concrete between expanded polystyrene foam panels, are very compatible with cold climate slabs, even when the upper part of the house is framed with studs. ICFs are an excellent option for the main house walls also. Studies have shown that their combination of mass and insulation helps temper interior temperature swings, even though the foam somewhat isolates the concrete (mass) from the living areas.

Interior heat-absorbing walls, made of concrete block, stone, or brick, can also serve to absorb solar heat. Masonry walls are commonly incorporated into fireplace or wood heater surrounds. With the creative use of decorative concrete block, or coverings (veneers) of stone, brick, stucco, plaster, or tile, heat-storing walls can become effective passive heating elements, as well as beautiful accent walls and focal points in a home.

Going Solar

Saving up to 80 percent on heating and cooling costs is possible when passive solar design techniques are combined with careful attention to insulation, caulking, and efficient supplemental heating and cooling equipment. The initial downside is that passive solar and energy-efficient design elements typically increase the cost of building a home by 10 to 15 percent over average construction costs. Alternative construction methods, green building materials, and active solar (solar hot water and solar-electric systems) will also add to these initial costs.

But the payback—reduced energy bills, better energy efficiency, and improved home comfort—are all part of the benefits of a well-designed home. Typically, energy savings will be greater than the increase in any mortgage payment—which makes the improvements pay for themselves from the start. Some lenders now offer energy efficiency and Energy Star mortgages, which allow increased loan amounts by factoring in a home's estimated monthly utility savings (see Access).

Katrina Cottage

Size: 1,236 square feet
 South-Facing Glazing: 10 percent
 Number of Bedrooms: 3
 Number of Bathrooms: 1.5
 Plan Complexity: Simple



Floor Plan



South (Back) Elevation

This three-bedroom home has a lot to offer in a modest foundation footprint. The southeast porch is a gathering area and is shaded from the hot western sun. It welcomes the morning rays and wraps around to the south patio for cookouts and winter lounging. The vaulted ceilings and unique walls add openness and character with little wasted square footage. The dining area will feel like a sunroom with its wraparound corner windows. The kitchen will be cool but sunny in the morning with the east-facing window box. The wood heater, surrounding hearth, and adjacent entertainment center are the focal point of the home. The stone, brick, or tile adds visual warmth to the interior while simultaneously providing thermal mass to absorb the heater and sun's heat in winter. A proper south orientation and overhang prevents the space from receiving too much sun in summer.

Sunshine 4

Size: 1,486 square feet
 South-facing Glazing: 11 percent
 Number of Bedrooms: 2
 Number of Bathrooms: 1.5
 Plan Complexity: Simple

Floor Plan



South (Back) Elevation



The Sunshine 4's relatively small building footprint lends to this home's potential for having a lower environmental impact than most conventional homes of its size. The side porch faces east for sunny mornings, and provides a cool place to relax on hot afternoons. The light in the great room and passive cooling of the entire house is aided with the daylight cooling chimney. With the addition of PV modules and a solar hot water system, efficient appliances and lighting, and a tendency toward thoughtful resource consumption, it would be easy to make this house a zero energy home.

Cottage Atrium

Size: 1,741 square feet (1.5 stories)
South-Facing Glazing: 10 percent
Number of Bedrooms: 2
Number of Bathrooms: 1.5–2.5
Plan Complexity: Complex



Southeast (Back) Elevation

The Cottage Atrium offers the benefit of a modest foundation footprint, but with the grandeur of a large central atrium. The central staircase is full of light, and also aids in natural cooling. A small second-floor loft accommodates additional family members in this two-bedroom home. The house is full of Sarah Susanka's *Not-So-Big-House* concepts: A corner of the house faces south, which maximizes the number of rooms that receive sun. The back corner sunroom is designed to face due south with the front of the house facing northwest.



Second Floor Plan

Main Floor Plan

Sunset Bungalow

Size: 2,481 square feet
South-Facing Glazing: 10 percent
Number of Bedrooms: 3
Number of Bathrooms: 2
Plan Complexity: Simple



West (Front) Elevation



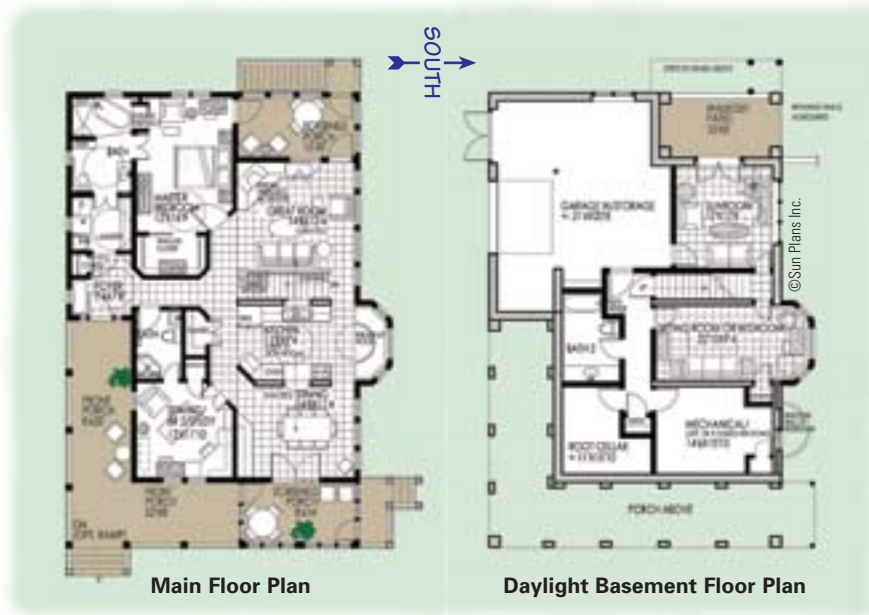
South (Side) Elevation

Fernwood

Size: 2,093 square feet (including 609 sq. ft. basement)
South-Facing Glazing: 9 percent
Number of Bedrooms: 4
Number of Bathrooms: 3
Plan Complexity: Simple



The Fernwood is designed to be constructed with a trussed roof, 6-inch-thick exterior walls, and an ICF foundation. The main floor has 8-foot-tall ceilings with the south rooms vaulted to the center. The north rooms could be vaulted too, but the flat ceiling allows for some attic storage above the north rooms. Thermal mass walls around the kitchen temper the strong winter heat gain if finished in tile, stone, or stucco. The daylight basement is designed with flexibility for one or two sunny bedrooms, as well as a sunroom or greenhouse. Root storage and mechanical rooms are on the cool, bermed north and west ends. A one-vehicle garage has been tucked into the east end of the basement, taking advantage of the excavated area and keeping the building footprint smaller.



The Sunset Bungalow can make its home in a traditional neighborhood with narrow lots or in the middle of the woods. Several sun tubes (aka tubular skylights) throughout bring light into the middle of the house. The long south wall allows for an abundance of solar gain in winter, yet the overhang will keep out the direct sun in summer. The slab-on-grade construction, resulting in a concrete floor that can be covered with tile, offers an economical way to add thermal mass to the structure. Since the sunroom is not tucked within the main house, its temperatures will swing a little more in the seasonal extremes, but the glass on east and west will allow for great views year-round and cross-ventilation in summer, just like a screened porch.



Midnight Sun

Size: 2,742 square feet (two-story, plus daylight basement)
South-Facing Glazing: 10 percent
Number of Bedrooms: 5
Number of Bathrooms: 3.75
Plan Complexity: Simple



The Midnight Sun's design—building up rather than out—offers lots of living space, with a building footprint that is ideal for small lots. The first floor and basement have 8-foot-tall walls, but since there is plenty of south glass, the rooms will not feel small. The second floor ceilings are sloped with no attic space. High shelves and exposed rafter ties add character. The foundation is ICF, upper floors use 2 by 6 construction, and rafter sizes vary with insulation requirements. Customized energy recommendations that accompany the blueprints contain other energy-related suggestions, such as how much rigid insulation to use in addition to the stud wall, and the type of glass that's best suited for your climate. The thermal mass is in the basement floor, stone-covered hearth, and tile floors over gypsum cement in the upper levels.



Access

Debra Rucker Coleman, Architect, AIA, Sun Plans Inc., PO Box 85, Citronelle, AL 36522 • info@sunplans.com • www.sunplans.com

Information and plans adapted from sunplans.com and *The Sun-Inspired House: House Designs Warmed & Brightened by the Sun*, by Debra Rucker Coleman, 2005, Paperback, 248 pages, ISBN 0976731800, \$29.95, distributed by Chelsea Green Publishing • 800-639-4099 • www.chelseagreen.com or online from Sun Plans Inc. • www.sunplans.com

Energy Star mortgages • www.hud.gov/energystar/lendersbrokers.cfm

Solar Site Analysis Tools:

Solar Pathfinder • 317-501-2529 • www.solarpathfinder.com

Solmetric SunEye • 877-263-5026 • www.solmetric.com

Wiley Electronics Acme Solar Site Evaluation Tool • 845-247-2875 • www.we-llc.com/ASSET.html

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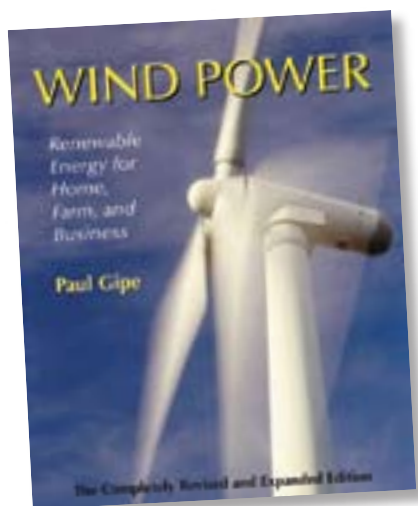
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RE-SOURCES

Wind Power

Do you want to learn more about wind-electric system siting, design, and installation? Wind energy is not the easiest resource to tap, and history is littered with examples of failures in design and implementation. The resources listed here will steer you in the right direction, so your experience with wind energy can be enjoyable and successful!

► If you only purchase one resource for your wind energy education, Paul Gipe's *Wind Power: Renewable Energy for Home, Farm, and Business*, should be it. At 512 pages, this comprehensive book covers much of what you need to know to successfully capture wind energy, including wind generator theory, practical system design information, and real-world examples of successes and failures. This book is the best value going if you're serious about understanding wind-electric systems. \$50 from Chelsea Green Publishing Co. • 800-639-4099 or 802-295-6300 • www.chelseagreen.com. For additional studies on wind energy topics, see also Paul's archive of small wind articles at www.wind-works.org/articles/small_turbines.html



► If you want to understand wind generator design, and get a handle on what it might take to design or build your own machine, pick up a copy of Hugh Piggott's fine book, *Windpower Workshop* (from New Society Publishers, www.newsociety.com, or directly from



Hugh at www.scoraigwind.com). And while you're at it, check out Hugh's Web site, which is full of good information on homebuilt wind generators, including step-by-step plans for his axial field design.

► For solid research on wind energy topics, take a good look at the "Small Wind Toolbox" at www.renewwisconsin.org/wind/windtoolbox.html. Papers on a wide variety of subjects, from permitting, zoning, and other legal issues, to birds, aesthetics, and sound will help you educate yourself and your neighbors about the issues you may face when planning a small wind-electric system.

► *Wind Energy & Wind Turbines* by Vaughn Nelson is a comprehensive introduction to wind energy on CD-ROM. Based on a college curriculum, it includes sections on energy, wind characteristics, instrumentation and measurement, wind turbine design, system performance, siting, the wind industry, institutional issues, and wind economics. See www.windenergy.org for more information and for online resources. \$25 from University Bookstore • 806-651-2744 • www.wtbookstore.com

► For networking with and perspectives from wind energy users, installers, consultants, and dreamers, there's nothing like the awea-wind-home e-mail list, hosted by the American

Wind Energy Association. To subscribe, send a message to: awea-wind-home-subscribe@yahoo.com. To read the archives, see www.groups.yahoo.com/group/awea-wind-home.

► A great resource for wind generator builders and renewable energy homebrewers, www.otherpower.com includes a discussion board, and lots of free resources and links. Subtitled "The Cutting Edge of Low Technology," this site is hosted by Forcefield, importers of neodymium magnets for wind turbines and fun.

► Folks in Denmark are wild about wind energy, and the Danish Wind Industry Association Web site at www.windpower.org/en/core.htm is chock full of information. The Danes know how to do wind—big and small.

► Claus Nybroe at Windmission has compiled a comprehensive list of wind turbine manufacturers at www.windmission.dk/workshop/wind%20sites.html. The page includes links to manufacturers of production turbines from all over the globe. While I suggest that you look carefully at whether these turbines are supported in your part of the world, the links on this site may help you when it's time to choose your turbine.

► If you're a teacher, a homeschooler, or someone else interested in education, check out the educational kits from Kidwind Project. Founder and director Michael Arquin is on fire to help kids understand wind energy, and he's for hire to teach your school's teachers how to do it well. Contact Michael at 781-354-2452 • www.kidwind.org

► If you want to install your own wind-electric system or prepare yourself to work in the industry, consider attending hands-on workshops. Look at turbine manufacturers' Web sites, and at www.solarenergy.org, www.the-mrea.org, and www.wind.appstate.edu

Thanks to my friends and colleagues Paul Gipe, Mick Sagrillo, Hugh Piggott, and Dan Bartmann for their recommendations for these listings.

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Courtesy Midwest Renewable Energy Association (2)

Classroom and hands-on experience is invaluable if you want to join the ranks of renewable energy professionals.

Get *Your* RE Start

COURSES, CLASSES & TRAINING OPPORTUNITIES

Laurie Stone

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The renewable energy (RE) industry is growing rapidly, and a wide variety of employment opportunities—from system design and installation to hardware development and engineering—are opening up on a regular basis. The first step in finding a career in RE is to assess what skills you have, what skills you'd like to learn, and what type of position would be most satisfying. But no matter what your chosen career path, a solid foundation in RE system design, component specification, and installation basics will make you a more attractive candidate to potential employers.



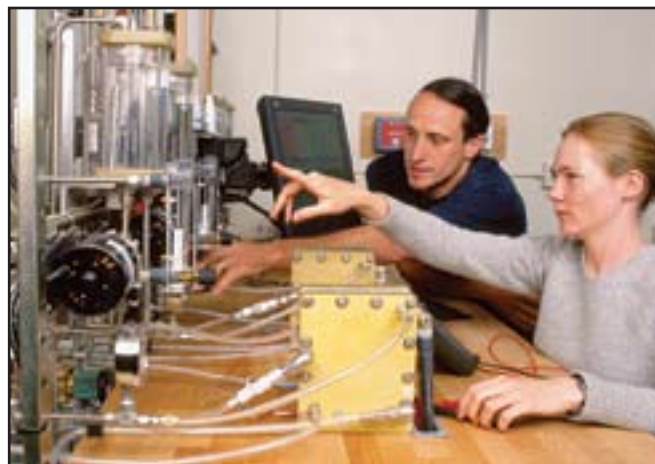
Courtesy Appalachian State University

This Appalachian State University student puts his RE skills to work on a wind generator tower.

Get Your RE Degree

If you're serious about an accredited renewable energy education, a handful of programs offered through universities provide degrees in renewable energy technologies.

Two-Year Degrees & Certificates. Lane Community College in Eugene, Oregon, offers a two-year associate of applied science degree in renewable energy technology, under their Energy Management Technician program. Lane's program prepares students for careers in the energy management field or as renewable energy system installers, with courses in electrical theory, PV design and installation, and energy efficient methods. Students learn to evaluate energy use patterns and make energy efficient retrofit recommendations for both residential and commercial buildings, and size and recommend PV systems, as well as



Courtesy Humboldt State University

Many university degree programs include laboratory components, allowing students the ability to experiment with and test various renewable technologies.

implement PV design protocol. In addition to coursework, students also complete a cooperative education requirement, which provides relevant field experience and networking opportunities with professionals.

The Renewable Energy program at San Juan College in Farmington, New Mexico, bases their curriculum on the science of the technologies, and then pairs this knowledge with design and installation techniques. Offerings include a concentration in Photovoltaic System Design and Installation, either as a two-year associate of applied science degree or a one-year certificate. The certificate program is appropriate for students who already have a college degree, or who currently work in a related industry. Coursework includes introductory physics, and PV theory and system design, as well as two courses on interpreting the *National Electrical Code*.

Going Pro

PV installation certification is one of the newest developments in the RE education movement. The nonprofit North American Board of Certified Energy Practitioners (NABCEP) has led this effort by establishing a certification program for PV installers and setting national standards by which PV installers with skills and experience can distinguish themselves.

NABCEP offers two PV exams—one for PV installer certification and one dubbed the Entry Level Certificate of Knowledge. To qualify for the 4-hour written exam required for PV Installer Certification, candidates must meet a few prerequisites, such as hands-on experience. Fees for the exam start at \$250, which includes a one-time application cost. For more information, visit www.nabcep.org

PV installers who want to receive NABCEP-approved training must study at an ISP-accredited institution. The ISP (Institute for Sustainable Power) oversees the accreditation process, and monitors programs to make sure they meet several requirements.

Coconino Community College in Arizona provides an associate of applied science degree in Alternative Energy Technology, a 58-credit-hour program that covers PV & wind-electric systems, as well as solar home design.

Many other community colleges are in the process of developing associate degree programs. Through a grant from the National Science Foundation, the Center for Sustainable Energy at Bronx Community College in New York is currently working to establish a degree program in Energy Services Technology and Alternative Fuel Vehicle Technology. Cape Cod Community College in West Barnstable, Massachusetts, also is establishing a broad-based Renewable Energy (RE) education and training program. For more listings of coursework offerings across the country, search the Interstate Renewable Energy Council's Web site at www.irecusa.org/courses.php.

Undergraduate & Graduate Degrees. Earn a bachelor or master of science degree in Environmental Resources Engineering at Humboldt State University in Arcata, California. Upper-level undergraduate courses include energy analysis of buildings, principles of hydro, wind, and photovoltaic energy production and systems, and solar thermal systems analysis and design. Humboldt's Campus Center for Appropriate Technology showcases environmentally friendly technologies, from solar cookers to PV systems, and provides experiential learning opportunities for students enrolled in university classes.

If you want more than just PV training, an undergraduate degree in Appropriate Technology at Appalachian State University (ASU) in North Carolina provides curricula in energy conversion systems, waste and water management,



Courtesy San Juan College

Students at San Juan College get practice with PV along with earning their associate of science degree or certificate.

community and shelter design, technology assessment, small-scale production systems, and technology transfer. ASU defines appropriate technologies as being "smaller scale technologies, that are ecologically and socially benign, affordable, and often powered by renewable energy," and says that their unique interdisciplinary program draws from the physical and social sciences, as well as engineering, architecture, and technology. Students gain exposure to drafting and design techniques, as well as a thorough

Higher Learning

Appalachian State Univ., Department of Technology, Boone, NC • 828-262-6361 • scanlindm@appstate.edu • www.tec.appstate.edu/at/app_tech.html • Bachelor of science, Appropriate Technology

Coconino Community College, Flagstaff, AZ • 928-526-7696 • www.coconino.edu/collegecatalog/0607/AASALTENERGY.htm • Associate of arts, Alternative Energy Technology

Colorado State Univ., Solar Energy Applications Lab, College of Engineering, Fort Collins, CO • 970-491-8617 • seal@lamar.colostate.edu • www.colostate.edu/Orgs/SEAL • Graduate degree, Mechanical Engineering

Georgia Inst. of Tech., Univ. Center of Excellence for PV, Atlanta, GA • 404-894-2000 • ucep@ee.gatech.edu • www.ece.gatech.edu/research/UCEP • Ph.D, Electrical Engineering

Humboldt State Univ. Env. Resources Eng. Dept., Arcata, CA • 707-826-3619 • ere_dept@Humboldt.edu • www.humboldt.edu/~ere_dept • Bachelor and master of science, Environmental Resources Engineering

Lane Community College, Science Division, Eugene, OR • 800-769-9687 • www.lanec.edu/instadv/catalog/science/programs/energy.htm • Associate of applied science, Renewable Energy Technician

Royal Inst. of Technology, Dept. of Energy Technology, Stockholm, Sweden • www.energy.kth.se • Master of science, Sustainable Energy Engineering

San Juan College Renewable Energy Program, Farmington, NM • 505-566-3003 • munsont@sanjuancollege.edu • www.sanjuancollege.edu/reng • Associate of applied science, Photovoltaic System Design & Installation; One-year certificate in PV Design & Installation

Sustainable Systems, Dept. of Parks & Recreation/Environmental Education, Slippery Rock University, Slippery Rock, PA • 724-738-2068 • daniel.dziubek@sru.edu • <http://academics.sru.edu/pree/ssgrad.htm> • Master of science, Sustainable Systems

University of Massachusetts, Mechanical Engineering Dept., Lowell, MA • 978-934-2968 • john_duffy@uml.edu • www.eng.uml.edu/dept/energy • Master of science, Energy Engineering

Univ. of New South Wales Centre for PV Engineering, Sydney, NSW, 2052 Australia • 011-612-93-85-4018 • pv.labs@unsw.edu.au • www.pv.unsw.edu.au • Master of science, PV Engineering

Univ. of Wisconsin Solar Engineering Program, Madison, WI • 608-263-1589 • beckman@engr.wisc.edu • <http://sel.me.wisc.edu> • Master of science, Mechanical Engineering or Chemical Engineering

background in PV design and installation, microhydro- and wind-electric systems, and solar thermal system design.

At the graduate level, Slippery Rock University's master of science degree in Sustainable Systems in Pennsylvania is an interdisciplinary program that addresses building design for energy efficiency and "alternative" energy technologies, along with ecosystem management and sustainable agriculture. Students at SRU can apply their studies in projects at the real-world lab—the aptly-named Harmony House, a demonstration center that integrates various sustainable designs and technologies, from a composting toilet to a 1.5-kilowatt PV system.

Graduate students in the mechanical engineering program at the University of Wisconsin–Madison get to practice solar science at the Solar Energy Laboratory (SEL), which has been recognized nationally and internationally for accomplishments in researching practical applications that use the sun's energy. SEL "emphasizes applications of engineering fundamentals to energy problems, and leads students to advanced degrees in mechanical and chemical engineering."

If you'd like to learn about PVs and other renewable energy systems outside of the United States, you can earn a master of science degree in Sustainable Energy Engineering at the Royal Institute of Technology in Sweden, or a degree in PV engineering at the University of New South Wales in Australia.

Many programs offer students the opportunity to work in the field installing renewable energy systems.



Courtesy Appalachian State University

More and more colleges and universities are adding renewable energy programs into their curricula, and the listings here are by no means exhaustive.

Basics for Beginners

Hitting the online highway may be your best bet for introductory or refresher courses. Several RE organizations offer Internet courses, from how to design a solar-electric (photovoltaic; PV) system or a passive solar home to how to implement renewables in the developing world.

Online courses generally run from four weeks to several months. Most online courses allow you to work at your own pace, on your own schedule. Instructors are generally available to answer questions, and grade quizzes and homework.

Workshop Offerings

Florida Solar Energy Center*, Cocoa, FL • 321-638-1000 • info@fsec.ucf.edu • www.fsec.ucf.edu

I-Renew, Iowa RE Assoc., Iowa City, IA • 319-341-4372 • irenew@irenew.org • www.irenew.org/workshops.html

Great Lakes Renewable Energy Assoc., Dimondale, MI • 800-434-9788 • jeremy.wittrock@glrea.org • www.glrea.org

Midwest Renewable Energy Assoc.*, Custer, WI • 715-592-6595 • info@the-mrea.org • www.the-mrea.org

New Mexico State Univ. SW Technology Dev. Inst., Las Cruces, NM • 505-646-1049 • tdi@nmsu.edu • www.NMSU.Edu/~tdi

North Carolina Solar Center, Raleigh, NC • 919-515-5666 • ncsun@ncsu.edu • www.ncsc.ncsu.edu

Northeast Sustainable Energy Assoc., Greenfield, MA • 413-774-6051 • nesea@nesea.org • www.nesea.org

Solar Energy Center*, Farmingdale State Univ., Farmingdale, NY • 631-420-2450 • dathatyn@farmingdale.edu • www.tech.farmingdale.edu/depts/met/solar

Solar Energy International*, Carbondale, CO • 970-963-8855 • sei@solarenergy.org • www.solarenergy.org

Solar Living Inst., Hopland, CA • 707-744-2017 • sli@solarliving.org • www.solarliving.org

SóLEnergy, Carbondale, CO • 970-963-1060 • sol@solenergy.org • www.solenergy.org

Sunnyside Solar, Guilford, VT • 802-254-4670 • info@sunnysidesolar.com • www.sunnysidesolar.com

West Texas A&M Univ. Alternative Energy Inst., Canyon, TX • 806-651-2295 • aeimail@mail.wtamu.edu • www.wtamu.edu/research/aei

For more workshop offerings, read "Happenings" in each issue of Home Power or go to www.homepower.com/events/index.cfm. The IREC Web site (www.irecusa.org/courses.php) also posts course listings.

*ISP-accredited organizations



Courtesy Solar Energy International

These SEI workshop students put the finishing touches on installing a roof-mounted PV array.

However, don't always expect an immediate response to your questions—you may have to wait a couple of hours or a couple of days, depending on how many students are in the course, and when you are online. SoL Energy offers six-week online courses on basic PV and utility-interactive PV. Solar Energy International (SEI) offers six-week-long courses on both PV design and solar home design. Prices range from \$300 to \$725.

Hands-On Opportunities. While online courses can provide you with a basic understanding of RE, hands-on training is necessary if you want to install systems, either at your own home or professionally. Hands-on workshops can range from two-day workshops (starting at \$160) up to two-week-long workshops (starting at \$1,500). While weekend workshops give a good overview of the technology, longer workshops will provide more hands-on instruction and more in-depth coverage of the different components.

For southerners, the Florida Solar Energy Center offers one-day to weeklong courses at their research and training facility in Cocoa, Florida. Their workshop offerings cover a range of topics: from PV installation to using RE for disaster relief to specific code issues. Most of their courses are geared toward professionals—journeymen, contractors, and inspectors.

Midwesterners can tap into offerings from the Midwest Renewable Energy Association, which facilitates one-day to two-week-long workshops, many at their solar- and wind-

powered headquarters in rural Wisconsin. Coursework includes beginner, intermediate, and advanced PV classes, women-only workshops, and PV site assessment. The Great Lakes Renewable Energy Association in Dimondale, Michigan, and I-Renew in Iowa City, Iowa, are other regional organizations that sponsor and host RE workshops, trainings, and seminars.

Solar Energy International (SEI), located in the mountains of western Colorado, also offers a series of PV workshops focused largely on hands-on instruction. In their PV Design & Installation workshop, students spend a week in the classroom learning about PV and a week out in the field learning how to install a system. SEI offers workshops in several states and internationally.

On the West Coast, the Hopland, California-based Solar Living Institute offers short, weekend workshops, such as beginner's PV courses for non-electricians and do-it-yourselfers, as well as a variety of others. Their Solar Living Center features a 132-kilowatt grid-tied PV array, as well as a number of other solar energy technologies.

Get Your RE Start

Once you decide what outcome you want from your training, you need to sift through the ever-growing number of schools, organizations, and institutions that offer training programs. The listings and Web resources provided will help you find the courses, seminars, or trainings that are right for you. Contact the organizations individually to find out more about the programs they offer.

Access

Laurie Stone, Solar Energy International, PO Box 715, Carbondale, CO 81623 • 970-963-8855 • Fax: 970-963-8866 • www.solarenergy.org • sei@solarenergy.org



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In battery-based renewable energy (RE) systems, a charge controller has one primary function—to prevent RE sources from overcharging the system's battery bank. Overcharging your batteries will result in increased maintenance and decreased longevity, and will quickly destroy sealed battery types. Your charge controller protects your battery bank—it's a critical component in any battery-based renewable energy system.

Over the last decade or so, charge controllers have evolved from relatively simple system components for disconnecting a solar-electric (photovoltaic; PV) array when the battery bank is charged, to full-featured units with intelligent charge regulation, array output optimization, automatic battery equalization, and even built-in datalogging. These days, if you pick the right controller, you'll have more energy stored in your battery bank at the end of the day, increased battery longevity, and more flexibility in system design.

This article will take you on a tour of some of the important features to keep in mind when choosing a charge controller, and show you a sampling of the charge controllers that are available in the United States for whole-house systems. Only listed controllers rated at 40 amps and above are included, and one controller from each manufacturer's line is featured. Charge controllers for smaller systems are not included here, but many of the controller features described in this article are desirable in those systems as well.

CHARGE CONTROLLER RATINGS

When selecting a charge controller, consider both its voltage and current ratings. Most of the charge controllers featured here can be programmed or configured to operate at different nominal battery voltages, but double check that the controller you select is compatible with your system's nominal battery voltage.

All PV charge controllers have an absolute maximum open-circuit voltage (Voc) rating. Exceeding this rating can damage the controller, and overvoltage-related failures are not covered under warranty. Because module voltage increases as temperature decreases, a temperature correction factor based on the historic lowest temperature at your site must be considered when determining the voltage of your PV array.

A controller's rated amperage should typically be 1.25 times the PV array's 25°C short-circuit current (Isc) rating (to account for edge-of-cloud or other enhanced irradiance effects and to meet *National Electrical Code* requirements), or 1.56 times the array Isc if the charge controller is not rated for continuous operation at rated current. Most maximum power point tracking (MPPT) controllers (described below) include an electronic current limit function, and are subject to the 1.25 derate factor. MPPT controllers operating in step-down voltage mode will have a significantly higher output current than input current. If you're using your controller in step-down mode, the *output* current needs to reflect the controller's current rating specification.

FEATURES YOU WANT

In addition to protecting batteries from overcharging, most whole-house charge controllers have many other features. Here are several to consider.

Maximum power point tracking. If you're installing a whole-house battery-based PV system, buy an MPPT controller. In most applications, MPPT controllers will generate about 15 percent more energy annually than systems with non-MPPT controllers. And they generate more energy when you likely need it most—during the winter when the PVs are cold, the array voltage is high, and the sun is not always shining. For more details on MPPT, see the sidebar on page 84.

Voltage step-down capability. Many MPPT controllers allow you to configure your PV array at a higher nominal voltage than your battery bank's nominal voltage. This design approach is common in modern systems. The reduction in wire, conduit, and installation costs can typically offset the price difference between MPPT and non-MPPT controllers.

Battery temperature compensation. Batteries operating at low temperatures should be regulated at a

higher voltage, and lower regulation setpoints are desirable when ambient temperatures are high. Battery temperature compensation allows the charge controller to automatically adjust the charge setpoints to account for battery temperature. Temperature compensation requires a remote sensor located at the batteries and connected to the charge controller, or to the communications hub in networked systems.

Remote control and monitoring. Many charge controllers include built-in voltage, amperage, and amp- and watt-hour metering for tracking system performance. Some controllers have an optional remote display that is typically wired to the controller with phone or Ethernet cable, which allows you to monitor system charging from the comfort of your living room or kitchen. Wireless remotes (now common in

batteryless grid-tie systems) are on the horizon for battery-based charge controllers.

Equalization. Equalization can be simply defined as a controlled overcharge of the battery bank. Equalizing flooded lead-acid batteries (sealed batteries should not be equalized) four to six times a year helps reduce sulfation, and actively mixes the battery electrolyte, both of which are necessary for increased battery longevity. The controller you choose should have either a manual or automatic equalization function that can be disabled if you're using sealed batteries.

Datalogging. Some charge controllers include relatively extensive datalogging functions. Charge history, such as daily and cumulative kilowatt-hour (KWH) production, will help you keep tabs on your system.

(continued on page 83)

Apollo Solar

Apollo Solar, a Connecticut-based company with a long history in power electronics design, has entered the renewable energy arena. Apollo recently released their new T80 TurboCharger MPPT controller. The T80 has a power output rating of 80 amps at 40°C (104°F), and the capability to charge several nominal battery voltages from a higher nominal voltage array. A built-in battery state-of-charge monitor (amp-hour meter) is included, and a wireless version of the monitor is in the works. We're looking forward to seeing how this new controller performs in the field.

Apollo T80 TurboCharger

Nominal battery voltage: 12, 24, or 48 VDC

Rated output current: 80 A at 40°C (104°F)

Maximum PV open-circuit voltage: 140 Voc

MPPT: Yes

Array voltage step-down options: 140 Voc maximum to 12–48 VDC nominal

Warranty: 10 years

MSRP: \$849

Blue Sky Energy

In 2001, Blue Sky Energy (formerly RV Power Products) became the first U.S. manufacturer to offer a listed, MPPT charge controller for battery-based PV systems. Their controller product line now has eight models, each specifically designed for various array and battery voltage combinations. In 2004, Blue Sky introduced their Integrated PowerNet (IPN) design, which allows up to eight IPN controllers to be networked together and to function in parallel with common regulation points. A remote display that includes battery state-of-charge monitoring is also available, and soon all IPN-compatible charge controllers will include variable dusk-to-dawn lighting control for the display.

Blue Sky Energy Solar Boost 50

Nominal battery voltage: 12 or 24 VDC

Rated output current: 50 A at 40°C (104°F)

Maximum PV open-circuit voltage: 57 Voc

MPPT: Yes

Array voltage step-down options: 57 Voc maximum to 12 or 24 VDC nominal

Warranty: 3 years, extended available

MSRP: \$432; with optional display, \$514





Morningstar

Morningstar manufactures two models of their TriStar controller (45 and 60 A), both of which are very popular for use as diversion controllers in wind- and microhydro-electric systems. The optional TriStar meter LCD display provides the user with in-depth instantaneous and historical charge information, including cumulative amp-hour (AH) and KWH data. The TriStar can be used as a load controller in systems with DC appliances. Morningstar also manufactures lower current, inexpensive charge controllers that are popular in developing world, RV, and marine applications, and small 48-volt, positive-ground controllers for telecom applications.

Morningstar TriStar TS60

Nominal battery voltage: 12, 24, or 48 VDC

Rated output current: 60 A at 45°C (113°F)

Maximum PV open-circuit voltage: 125 Voc

MPPT: No

Array voltage step-down options: No

Warranty: 5 years

MSRP: \$218; with optional display, \$317



OutBack Power Systems

The introduction of the OutBack MX60 controller changed the way battery-based PV systems are designed and installed. The MX60 was the first, and is currently the only charge controller to allow for array voltages of up to 150 Voc (72 V nominal in most locations). This is coupled with extremely flexible array and battery configuration options. The MX60 employs an advanced, active MPPT charging algorithm, 64 days' worth of onboard datalogging, and a four-line, 80-character LCD display. It can be networked with both OutBack inverters and other MX controllers to create a fully integrated system.

OutBack MX60

Nominal battery voltage: 12, 24, 32, 36, 48, 54, or 60 VDC

Rated output current: 60 A at 25°C (77°F)

Maximum PV open-circuit voltage: 150 Voc

MPPT: Yes

Array voltage step-down options: 150 Voc maximum to 12 to 60 VDC nominal

Warranty: 2 years, extended available

MSRP: \$649



Hantrex

Xantrex (formerly Trace Engineering) designed and manufactures the SW series inverter and the C40 charge controller, both of which paved the way for the second generation of RE power electronics. The C40 charge controller was at one time the industry standard, and for good reason. It's robust and offers three field-selectable nominal battery voltage options. The advent of MPPT controllers for PV systems resulted in the C40 being installed primarily as a diversion controller for wind- and microhydro-electric systems, and also as a DC load controller. Keep an eye out for their new MPPT controller, coming soon.

Xantrex C40

Nominal battery voltage: 12, 24, or 48 VDC

Rated output current: 40 A at 25°C (77°F)

Maximum PV open-circuit voltage: 125 Voc

MPPT: No

Array voltage step-down options: No

Warranty: 2 years

MSRP: \$159; with optional display, \$258

Specification Terminology

Nominal battery voltage

The named battery voltages (for example: 12 V, 24 V, or 48 V) a given charge controller is designed to interface with. Most whole-house charge controllers can be manually configured or programmed to work with any one of two or more nominal battery voltages.

Rated output current

The maximum amperage a charge controller is designed for. The rated current for MPPT controllers operating in step-down mode must always be based on the *output* current of the charge controller. Make sure to inquire about how *NEC* derate factors effect array amperage sizing for your particular controller.

Maximum PV open-circuit voltage (Voc)

The absolute maximum voltage a charge controller is designed for. Array voltage will be higher when operating at cold ambient temperatures, and a maximum voltage correction calculation based on the coldest historical temperatures for a given site is required. Subjecting controllers to higher-than-rated voltages may damage the controller and will not be covered under warranty.

Maximum power point tracking (MPPT)

PV arrays have a specific point on their power curve (current vs. voltage) where maximum power is achieved. Array voltage has an inverse relationship with array temperature—as an array heats up, its voltage drops. The result is a maximum power point that varies throughout the day. MPPT charge controllers are designed to closely follow the array's maximum power, which results in higher daily energy production, especially at low ambient temperatures or battery voltages.

Array voltage step-down options

MPPT charge controllers typically allow a PV array to be configured at a higher nominal voltage than the system's battery bank. This is the preferred installation approach in many applications because it reduces losses in transmission wiring, allows for smaller-gauge wiring between the PV array and the controller, and results in a wider voltage window for the controller to track the array's maximum power point.

Warranty

The length of time after purchase that a manufacturer will repair failed equipment due to defective parts or workmanship free of charge. Like most products, the conditions of a given warranty are clearly defined, but vary widely. Read the details carefully. Extended warranties are available from some manufacturers at an additional cost.

MSRP

The manufacturer's suggested retail price in U.S. dollars. Street prices may be lower, but design assistance and technical support from retailers offering the lowest prices will often be lower too.

ON THE HORIZON

An additional charge controller that is under development but not currently in production deserves mention. MidNite Solar is currently developing an MPPT controller for PV, wind, and microhydro applications. Significant design attention is being focused on developing features for regulation and optimization of residential-scale wind turbines. Tentative specs include a 60-amp capacity, 150 Voc maximum voltage rating, and the ability to integrate with 12 to 72 VDC nominal battery banks. A high-voltage (200 VDC) unit is also in the works.

FREQUENTLY ASKED QUESTIONS

Why does my battery-based RE system need both a charge controller and a battery charger?

The charge controllers featured here regulate energy input from RE sources like PV arrays, wind turbines, or microhydro generators. You'll generally need a separate controller for each RE charging source. Think of your battery as a tank with multiple pipes filling it. Each pipe needs its own valve to regulate the source when the tank gets full.

Most residential-scale, battery-based inverters have a battery *charging* function built in. This battery charger is used to convert AC electricity to DC electricity to charge the battery bank from an engine generator or the grid when the sun isn't shining, the wind isn't blowing, or the water isn't flowing.

Do I need a charge controller in a grid-connected PV system with battery backup?

Yes! In normal operation, while connected to the grid, a battery-based PV system doesn't use its charge controller for regulating the charge to the battery. The inverter is designed to export any surplus renewable energy to the grid, and in effect acts as a regulator to keep the batteries from being overcharged.

Wind & Microhydro Charge Controllers

Battery-based wind- and microhydro-electric systems require charge controllers, but controllers operate in a different mode in these systems. When a PV module is disconnected from a battery or load, it becomes an inert sheet of glass and silicon in the sun. But if some wind or microhydro turbines are disconnected from a full battery, their speed may increase to the point that they self-destruct or damage equipment due to overvoltage conditions.

To avoid this, the charge controllers for most wind turbines and microhydro systems route the extra energy from the battery to a "dump load"—an air or water heater. This diversion-control strategy always keeps the turbine electrically loaded, which in turn controls the turbine's rpm. Several of the charge controllers featured here can function either as solar (series) controllers, or as diversion controllers, depending on what your application requires.

What's the Big Deal about MPPT?

Maximum power point tracking (MPPT) for PV arrays is the newest feature being integrated into many whole-house charge controllers. PV modules' voltage and current vary throughout the day depending primarily on temperature. MPPT uses a mathematical algorithm to "track" the optimal point of production of a PV array to maximize annual energy generation.

In most locations and applications, an MPPT controller will increase the annual output of your PV array by about 15 percent. Hot climates (like Palm Springs, California) will see a smaller increase in energy gain compared to colder places (like Denver, Colorado) because PV voltage decreases as the module temperature increases.

Here's an example of why MPPT controllers are beneficial. It's a cold winter day and your batteries are at a relatively low state of charge and voltage (12.3 VDC). Let's assume that the array is rated for 34 amps at 17.5 volts. Because it's cold, the array's maximum power point is actually 19.5 volts. A non-MPPT controller will operate the array at the battery voltage, in this case about 12.3 VDC. The array amperage may be a little higher at the lower voltage, say 36 amps. So in this example, the total wattage charging the batteries is 443 watts ($36 \text{ A} \times 12.3 \text{ V}$).

If you use an MPPT controller, the array will operate at its maximum power point, producing 663 W ($34 \text{ A} \times 19.5 \text{ V}$). Even if the charge controller is only 95 percent efficient, it will still deliver 630 watts to the batteries, an increase of 187 W compared to a non-MPPT controller. As the array heats up, and the battery voltage rises during the daily charging cycle, the additional energy harvested by the MPPT controller will decrease.

In the summertime, the array will be operating at a high temperature and its voltage will be relatively low. In addition, the batteries will typically be at a higher state of charge due to long sunny days. Under these conditions, the performance of an MPPT controller and non-MPPT controller may be about the same. But the bottom line is that an MPPT controller will increase your PV array's annual production, especially during the short sun days of winter. The MPPT controller may cost \$600 instead of \$200, but that additional \$400 gets you increased energy harvest when you need it most, year after year, and can often be offset right out of the gate by decreased wire and installation costs.

Another reason to use an MPPT controller is that nonstandard PV modules are becoming more common. Many modules designed for grid-tied PV systems are no longer being made with the industry standard of 36 or 72 cells. Panels with 40, 42, 60, or other numbers of cells are becoming more common, and some new technologies produce higher voltage per cell. An MPPT charge controller can easily convert an odd voltage array into a usable array for battery charging.

However, there are two reasons why battery-based grid-tie systems need a charge controller. First, an MPPT controller will increase the output of the PV array, and maximize annual energy production. Second, if the grid shuts down, there is nowhere for the inverter to export or "dump" excess PV-generated electricity. In this scenario, until the grid is back on line, a charge controller is necessary to prevent battery overcharging.

I'm planning to install a whole-house, off-grid system, but need to start small and purchase additional PV modules as my budget allows. What size charge controller should I buy?

Buy a charge controller that is rated for the total amperage of the projected PV array. Otherwise, you'll end up buying a larger replacement controller as the system grows.

My PV array is going to be mounted pretty far from my battery bank (about 250 feet). What nominal voltage should I design for?

Most MPPT controllers allow you to operate the PV array at a nominal voltage that is higher than the nominal voltage of the battery bank. This voltage step-down feature fundamentally changed the way installers design battery-based PV systems. For example, these days it's common to wire a battery-based PV array at 72 VDC nominal to charge a 48 VDC battery bank, or a 48 VDC nominal array to charge a 24 VDC battery bank. Higher array voltage means simpler array wiring, lower current, smaller wire and conduit between the array and batteries, and arrays being located farther from the battery bank if the site demands it.

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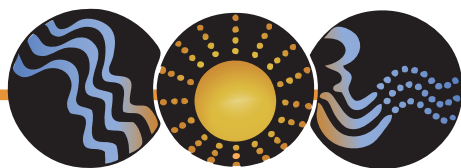
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Soaking in the Sun



George Blakey

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Above: Flat-plate solar collectors provide hot water and space heating for the pool house. **Right:** Large, south-facing windows admit an abundance of natural light and warmth into the building's interior. **Below:** Teachers and students practice the art of Watsu in the sun-warmed water and tranquil space.



Passive and active solar heating, combined with energy efficient building materials, give this Colorado-based aquatic center an edge on energy savings and long-term sustainability.



Courtesy Cliff Grassmick (2)

The difficulties of renting pool time to practice aquatic therapy originally motivated Watsu practitioners Greg and Debbie Ching to consider constructing their own pool house on their 2.5-acre home site in Nederland, Colorado. But their commitment to solar energy—and the energy and financial savings it offers—brought them to the doorstep of Solar Works Construction, my solar and general contracting business.

The Chings dreamed of having a facility where they could practice Watsu (aquatic massage) themselves, hold classes, and open it to other practitioners and their clients. To do so, they needed a pool about 20 feet square and 4 feet deep, with water that could be maintained near body temperature. They also wanted an office, a bathroom, and a room for table massage. As a designer and builder promoting sustainability, what was most compelling to me was the Chings' interest in extending their philosophy of caring for people to caring for the environment.

Efficiency in the Details

Debbie and Greg were already committed to and familiar with using renewable energy, and wanted to use solar energy to heat the new building and the pool water. Correctly siting the building to take advantage of passive and active solar heating opportunities was key. The building's roof ridge runs east and west, providing a large south-facing surface for an array of solar hot water collectors. A large bank of double-paned windows on the building's south face allows sunlight in, and the thermal mass of the concrete floors captures, stores, and reradiates this solar-made heat into interior spaces. A special film in the Heat Mirror windows

The Chings' home and pool house take full advantage of the sun's energy for electricity, and space and water heating.



Courtesy Greg Ching

The pool house's walls were constructed using insulating concrete forms (ICFs).

Green Home Upgrades

Being environmentally conscious is not new to Debbie and Greg Ching. When they moved into their 1970s-era home eleven years ago, they began immediate efficiency upgrades to their all-electric, wood-framed house. They replaced old wood heaters with newer, more efficient models, which allowed them to reduce the use of the electric furnace and baseboard heat, and rely more on an abundant local renewable resource—firewood. To help slow heat loss through the home's windows, they hung insulating shades. And bulb by bulb, they replaced nearly all of the incandescent lighting in the house with compact fluorescent lightbulbs. They also abandoned their electric clothes dryer in favor of a solar dryer (clothesline).

Although the house came with two solar hot water collectors mounted on the roof, they were not working. Greg and Debbie replaced them with four, 4- by 10-foot SunEarth collectors, which provide about 90 percent of their household hot water needs. A custom-designed 180-gallon tank stores the solar-heated water. With the future in mind, the Chings specified that extra heat-exchange loops be installed in the tank, which will allow hot water to be routed to a radiant floor heating system or to revitalize an old hot tub (which hasn't been used since the pool was built).

In 1999, they installed a 2-kilowatt (KW) grid-tied photovoltaic (PV) array, with a small battery bank for backup during occasional utility outages. Roof space was already at a premium with four solar hot water collectors taking up the south-facing space, so a ground-mounted PV rack was used. In addition to their PV system, Greg and Debbie also bought into the Windsource program through Xcel Energy, the major electricity provider in Colorado. With this program, anyone buying electricity from the grid can pay an extra charge per month (about \$3.75 for every 100 KWH) to ensure that their electricity use is offset by an equivalent amount of wind-produced energy.



Greg and Debbie Ching (and dog Casey) at their Nederland, Colorado, home.

Thick concrete floors in the pool house absorb and reradiate the sun's heat.



Courtesy Cliff Grassmick

slows heat transfer back through the south-facing windows, especially when outdoor temperatures drop into the single digits. These windows allow more solar heat to enter than ones with other low-emissivity (low-E) coatings.

Insulating concrete forms (ICFs), large polystyrene foam forms that are stacked and filled with steel-reinforced concrete, make up the pool house walls. This system produces a fire-resistant, sound-dampening shell with low air infiltration and an R-33 performance rating. For even more fire-resistance, plus low maintenance, the Chings chose a fiber-cement panel siding for the exterior finish that could be stained to match their house. Ten-inch-thick structural insulated panels (SIPs)—styrene foam faced with oriented strand board—comprise the roof and ceiling system, and insulate to about R-38. Like the ICFs, this product provides a tight,

well-insulated roof that is little affected by the humidity created by the warm pool water.

The concrete-and-plaster in-ground pool risked losing a substantial amount of heat to the earth. To slow heat loss, 2- to 4-inch-thick extruded polystyrene rigid insulation was added to the inside of the foundation wall, underneath the slab, and to the outside of the pool shell, insulating the pool and foundation walls to R-20, and the concrete slab to R-10.

Sun-Heated Floors & Pool

Fourteen SunEarth solar hot water collectors mounted on the building's roof supply the majority (about three-quarters) of the building's hot water needs—for warming pool water and for radiant floor heating. Almost 2,000 feet of Kitec tubing embedded in the concrete floors and routed into the ceiling of the massage room move the solar-heated water throughout the building for space heating. A custom-built, insulated solar storage tank holds water heated by the collectors.

A propane-fired backup boiler helps when the weather is very cold and cloudy, but, for most of the year, the solar heating system is enough to warm the pool water and building. On average, Greg says that they spend about \$100 per month on propane to heat the pool building and the water—less than one-quarter of the expense comparable facilities incur in this climate.

Along with the pool house came increased electricity use. The Chings decided to expand the existing PV system at the site to compensate. A 3.9-kilowatt (KW) PV array was set up just south of their home's array, on a lower, longer, ground-mounted frame. At the same time, the battery bank was doubled in size, to increase the backup capacity for their home and pool house. Some of the circuits in the new pool house, like lights and the pump for the solar hot water system, were wired to a subpanel for battery backup, while the nonpriority loads were connected to the grid-fed service entrance panel.



Inside the utility room—a glimpse of part of the hydronic heating system.

Other Efficiencies

A heat-recovery ventilator (HRV) improves the efficiency of the mechanical ventilation system by reclaiming energy from exhaust airflows. By using heat exchangers to heat or cool incoming fresh air, HRVs recapture 60 to 80 percent of the heat or cold that would otherwise be lost. Incoming and outgoing airflows pass through different sides of the heat exchanger (but are not mixed), allowing conditioned exhaust air to raise or lower the temperature of incoming fresh air. After passing through the heat exchanger, the warmed or cooled fresh air goes through the HVAC air handler, or may be sent directly to various rooms.

The Chings also incorporated many of the same efficiency measures they implemented in their home into the new pool house to keep its energy use as low as possible. During the day, the large windows admit ample natural light into the pool house, and tubular skylights in the utility room and office light these inner rooms. At night, compact fluorescent bulbs provide lighting. Insulating shades fitted to the large windows can be lowered or raised with the flick of a switch. Low-flow showerheads help reduce the water heating demand, and an ultra-low-flush toilet curbs water use. To minimize the loss of pool water due to evaporation and to reduce heat loss in the pool, a retractable cover is kept closed when the pool is not being used.

Tech Specs

Solar Pool Overview

System type: Drainback solar hot water with single-loop, in-tank heat exchangers

Location: Nederland, Colorado

Solar resource: 5.5 average daily peak sun-hours

Production: 13.5 million Btu per month average (3,940 KWH/month)

Climate: Eastern Rocky Mountains, 7,913 ft. elevation; sunny, cold winters; warm summers

Percentage of hot water produced annually: 75 percent

Solar Equipment

Collectors: 14 SunEarth, Empire Series, EC40, flat plate, 4 x 10 ft.

Collector installation: Roof mounted, south-facing at a 51-degree tilt angle

Heat transfer fluid: Water

Circulation pump: Taco 0011-BF4

Pump controller: Tekmar 155

Storage

Tank: Industrial Solar Technology, custom: steel frame with rubber liner, approximately 460 gallons

Heat exchangers: Two $\frac{3}{4}$ -inch copper coils in tank to radiant heating system; one 1-inch copper coil in tank to pool

Backup DHW: Buderus L160, side-arm, 42.3 gallons

System Performance Metering

Thermometers: Two, Tekmar 155

Pressure: USG, dial, 0 to 100 psi

Radiant Floor System

Tubing: Kitec XPA

Boiler: Buderus G124

Amount of tubing: 1,900 ft.

Number of zones: Three (two in floor, one in ceiling/baseboard)

Circulation pump: Three Taco 007-F5

Pump controller: Goldline SP-30

Zone valves: Two Taco boiler/solar feeds

Other Equipment

Pool heat exchanger: 1-inch copper coil in tank; Pahlen 260 for boiler line

Valve controller: Tekmar 155

Stellar Solar Success

The solar hot water collectors and passive solar design meet at least 75 percent of the heating needs of the pool and the building. Without the backup propane water heater, the solar hot water system keeps the pool temperature in the low 90s. The PV system meets about 75 percent of their summertime electrical needs, and offsets about 30 percent of the electrical demand in the winter.

The Chings were unable to take advantage of any financial incentives for solar energy at the time their system was installed—no rebates for PV or solar thermal systems existed that were applicable to their systems. But today, with the their utility's rebate program and federal tax credits, Debbie and Greg are planning to add another array, expanding their PV system to the utility's financed maximum of 10 KW. Payments for renewable energy credits from their existing systems are also available, which means they may be able to get up to \$2.50 per installed DC watt.

To further offset the project's expense and to share the splendor of the pool house and setting, the Chings now hold classes there, recruiting certified water-therapy instructors to teach students from all over the globe. And, of course, at the same time Debbie and Greg Ching are fostering a sense of community, they're also showcasing solar technologies, furthering the future of renewable energy.

Access

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Turning Waste into Fuel

Ilan Adler

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Methane Biodigester Basics



Top left: A gas storage unit, fully charged with ready-to-use biogas. Renewably generated methane has a number of uses, including cooking and heating.

Middle left: A technician inside the tubular biodigester tightens the gas output fittings. After the plumbing is finished, the digester will be filled with a mixture of water and manure.

Bottom left: Nutrient-rich liquid from the biodigester can be field-applied as a fertilizer.

Above: The author tests a biogas-fueled kitchen stove at Doña Tana's home in Michoacan, Mexico.

Doña Cayetana (Tana) holds a special status in the tranquil village of Eronga, in the highlands of the state of Michoacan, Mexico. She was the first one in town to have a homemade biodigester, which supplies biogas for most of her cooking and heating needs. The freedom from expensive LP gas or other less desirable sources of energy, such as firewood (commonly used in the area), has empowered Tana in many ways, providing not only a better quality of life, but also bringing journalists, students, and entrepreneurs from far points of the country to her modest house near the center of the village.

"Three pigs is all it takes," she says with a smile. But of course, it could be rabbits, cows, horses, or any other domesticated animal (including humans) that produces sufficient manure to feed a biodigester. For that is the main fuel involved—organic waste, which by being processed in this ingenious device is turned into fuel and nutrient-rich fertilizer.

What is Biogas?

If you want to know how a biodigester works, consider the human digestion system. Whenever we ingest any type of food, enzymes and bacteria in our stomachs and intestines start working on decomposing the long chemical chains of organic matter into simpler forms that our cells can feed on. The remains are excreted as much simpler, decomposed molecules. As a side product of this process, a usable gas, commonly known as biogas, can be captured.

Biogas is, and will always be, a fancy game of statistics. In any particular case, there is no way of predicting what exact percentage of the mixture each individual component of the gas will have, save by the most disciplined analysis.

Common Biogas Mixture

Component	Percent
Methane (CH ₄)	50–70%
Carbon dioxide (CO ₂)	30–40%
Hydrogen (H ₂)	5–10%
Nitrogen (N ₂)	1–2%
Water vapor (H ₂ O)	0.3%
Hydrogen sulfide (H ₂ S)	Trace amounts

Source: Instituto de Investigaciones Eléctricas (IIE), Mexico, 1980

The mix will vary depending on the type of manure and the climate the biodigester is in. The table above gives an idea of what to expect in most cases.

So what can we use all these gases for? It turns out that only one of them has any practical application, as far as our modern technology is concerned. Carbon dioxide (CO₂) we might just as well discard. It's a greenhouse gas and there's loads of it around, wherever creatures are breathing, organic matter is decomposing, or fossil fuels are being burned. Hydrogen sulfide is actually poisonous, and we have to filter it out, or at least try to ignore its nasty, pungent smell. There's not much use in the water vapor, unless you want a rather smelly steam bath. The main one left is CH₄, good old methane.

Fuel for the Fire

Methane is the flammable component in biogas—without it there would be no fire. This odorless, colorless gas can heat a stove, fuel a vehicle, or provide electricity to a community. Much of what we call “natural gas” is, in fact, methane.

One downside is that it is a very powerful greenhouse gas, 23 times stronger than CO₂, and that's saying a lot. One major advantage of a biodigester is that it generates methane that we can safely use, and also prevents it from escaping into the atmosphere as a greenhouse gas.

ADOPT A BIODIGESTER

Would you like to help a rural family build its own biodigester? The International Renewable Resources Institute (IRRI-Mexico), a registered nonprofit organization, is launching a campaign to link people or groups interested in supporting eco-friendly technology development in communities in Mexico that would benefit from these projects.

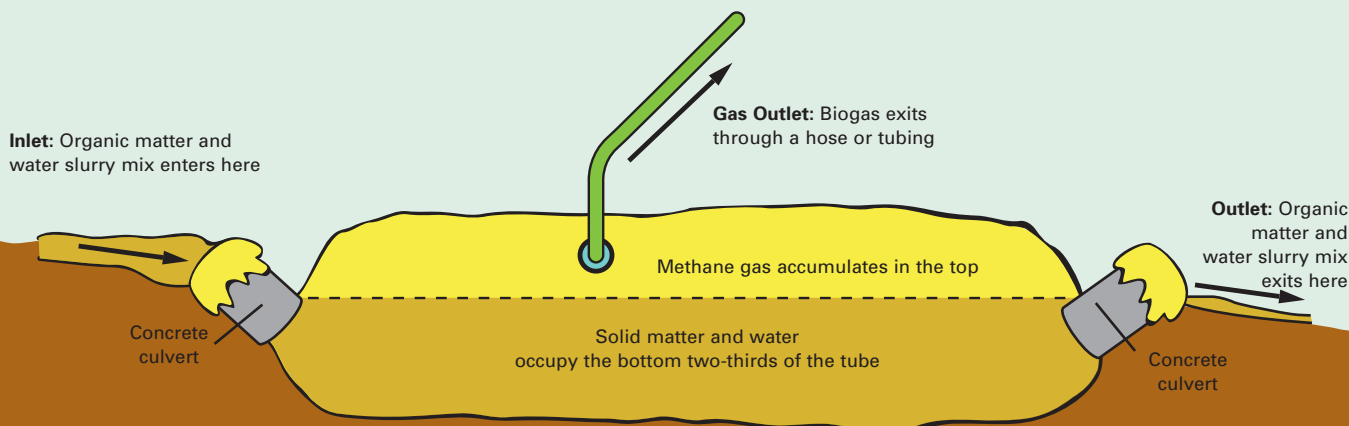
In the Adopt-A-Biodigester project, donations will be directly transferred to selected families in the form of basic tools and equipment to install a homemade biodigester. Sponsors will be able to know exactly how every dollar donated is used, the contact information of their adopted family, and may have the opportunity to participate as a volunteer in the installation! For more information, please contact info@irrimexico.org, or visit www.irrimexico.org.

Have you watched the bubbles that form in a swamp or in stagnant water? If the answer is yes, it's likely that you have seen methane as it is being formed underwater. Remember, all we need is enough organic matter, no oxygen, and anaerobic bacteria. All these can be found in a swamp, as the stagnant fluid loses all of its oxygen, especially in the bottom, and the decaying leaves and debris provide the nutrients. For the bacteria to thrive, we need adequate heat. In general terms, the warmer, the better (as long as it's not boiling hot). That's why biodigesters fare better in tropical climates.

Biodigesters

If we want to artificially recreate the methane production process in a controlled manner, we can make an airtight space into which we can put enough organic matter and guarantee the right conditions for bacteria to grow. Sounds

TUBULAR PLASTIC BIODIGESTER ANATOMY



CONSTRUCTING A TUBULAR BIODIGESTER



1

1. The plastic material is doubled up by pulling one end of the tube inside itself. This makes for a more durable, double-walled digester.



3

2. Farmer Juan Luis Salazar finishes digging the ditch for the biodigester, while workshop participants inspect the hole.



2

3. One of the concrete culverts is set into place at an angle.

4. The plastic tube is pulled through the concrete culverts at each end of the ditch, folded back, and tied with strips of inner tube.



4

easy, but how do you make an airtight space in which to add the wastes without having air enter the closed chamber and ruin the whole process? The key lies in the use of water.

Water acts as a perfect seal against air. Readily biodegradable organic matter can be fed into the device by passing it through water in an air-lock design to keep the digesting material enclosed.

A biodigester can be any container that will hold soluble organic matter without letting air in, and that provides enough space for biogas to accumulate. The container or chamber can be made from a variety of materials—ferrocement, concrete, plastic, even metal—as long as it doesn't have any leaks. The size of the chamber is determined by the amount of gas required, which also determines the amount of manure needed.

I prefer tubular plastic biodigesters. These use the same plastic used for greenhouses; it is locally manufactured in Mexico and many parts of Central America and has a relatively low cost. This type of digester retains heat much better than concrete or ferro-cement digesters. The material

must be UV treated, and ideally covered by some sort of roof to shield against excess sunshine and rain, as well as against physical damage. It is also necessary to dig a trench so that the tubular plastic will stay in place and be protected from the wind. Using PVC tubing and connecting valves, it is relatively simple to plumb the gas line to the house.

Using a Biodigester

The digester is initially filled with water until it overflows. This creates an air lock, with water in the lower two-thirds of the tube and air in the top third. Then a daily "charge" of manure-water slurry is added. The bacteria start decomposing the organic matter once it's in the chamber. The time they take to complete the process is called the retention time of the biodigester. As the matter flows through the container, biogas begins to accumulate in the upper part of the digester. This gas can be transported to the kitchen by a hose or tube fitted with a valve, or it can be stored in a separate plastic tube.

For the first few weeks, the only gases obtained will be a mixture of air and CO₂, from what was remaining in the



This biodigester was constructed at an SEI workshop in Mastatal, Costa Rica.

5



6

5. The biogas output tubing is attached before the tube is fully inflated.
6. The fully inflated tube. The tube is filled with water until it overflows, creating an air lock.

7



8

7. The author mixes manure with water to make a slurry.
8. The slurry is poured into the digester.

container at start-up time. Depending on the temperature and the type of manure used, it may take between 15 and 45 days to produce usable gas (production occurs quickly in warm, tropical climates).

Ideally, the biodigester should be charged daily with a mixture of water and organic matter in a fixed ratio. The new daily load will push water out through the exit tube. This water is partially treated, making it ideal for use in irrigation or, with more advanced purification and filtering, potable water. Several successful projects in Mexico have used biodigester effluent for aquaculture or horticulture, given the high amounts of dissolved nutrients that it contains. Plants irrigated with this effluent tend to grow better and stronger, without requiring additional chemical fertilizer.

Sustainable Development Tool

In the absence of a good treatment system, animal manures tend to accumulate in stagnant creeks or ravines, polluting groundwater and attracting disease-carrying insects.

A biodigester is a tool for sustainable development, providing biogas to cook, heat, or generate electricity, and is also an efficient means to reclaim a waste product, which would otherwise create greenhouse gases and health hazards. Methane biodigesters are low-budget, appropriate technology. They can be used widely in the developing world and elsewhere, turning waste into usable fuel and fertilizer.

Access

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Tony's TechTalk



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Beauty is in the Eye of the Inspector

John Wiles

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With electrical lifetimes exceeding 40 years, photovoltaic (PV) systems must be installed using the best available workmanship to ensure public safety over the life of the system. While the 700-plus pages of the *National Electrical Code* establish numerous requirements for electrical and mechanical procedures, the *Code* does not describe how many of these operations should be performed and how the final installation should look. This article will illustrate some areas that need attention before the workmanship of a PV installation is inspected. Of course, the local authority having jurisdiction (AHJ) has final approval of the workmanship.

Modules

PV modules must be securely mounted to a supporting structure. Mounting holes are provided in the frames of PV modules, and have been tested under simulated high wind loads to ensure that the module can withstand normal and expected environmental conditions. The hardware used to attach modules to a racking system must be appropriately sized and also be weather-resistant. Stainless steel hardware is most commonly used. Hardware used to secure PV modules to a building's roof must be robust and connect the mounting rack directly to the structural elements of the roof, such as the trusses or rafters. Attachment to only the roof sheathing generally will not provide adequate strength. All penetrations must be sealed with an appropriate sealant for the roofing material.

Many PV modules now have exposed, single-conductor cables attached to the backs of the modules. While Section 690.31 allows these exposed conductors, they should be used only to make connections between the individual modules, and should be terminated under or very near the PV array. There, the array output wiring should transition to one of the more common *NEC* Chapter 3 wiring methods, such as conductors in electrical metallic tubing (EMT). In general, these exposed, single-conductor cables, with attached connectors, will be longer than necessary when the modules are mounted side by side. The cables should not be allowed to droop, which could expose them to abrasion damage from wind and ice. Control this extra length by gathering the excess cable and connectors and fastening them to the module racks. Fastening hardware should be robust—stainless-steel pipe clamps in various sizes with EDPM rubber inserts are effective, but other options are available, including clips specifically designed to be used in conjunction with PV modules. Be wary of plastic cable

ties—especially the white nylon variety—they do not resist heat and ultraviolet light exposure well.

Bare, equipment-grounding conductors should also be afforded the same mechanical protection as the exposed, single-conductor, insulated circuit conductors. When these bare conductors are spliced, the proper device must be used—usually a copper split bolt.



UV- and moisture-resistant cables on the back of a PV module.
Inset: Stainless steel mounting hardware resists corrosion.

Exposed Conduit Runs

Unless the provisions of Section 690.31(E) in the 2005 *NEC* have been followed and the PV circuits are run in metallic raceways through the attic, the PV output circuits from the PV modules must remain *outside* the house until they reach the readily accessible PV DC disconnect (690.14). Conduits running across roofs and down the sides of houses and buildings must be appropriately supported and attached to the structure. Appropriate hardware must be used (again, stainless steel is popular) and any structural penetrations must be sealed to prevent weather intrusions. In most cases, the code establishes support requirements for the various wiring methods.

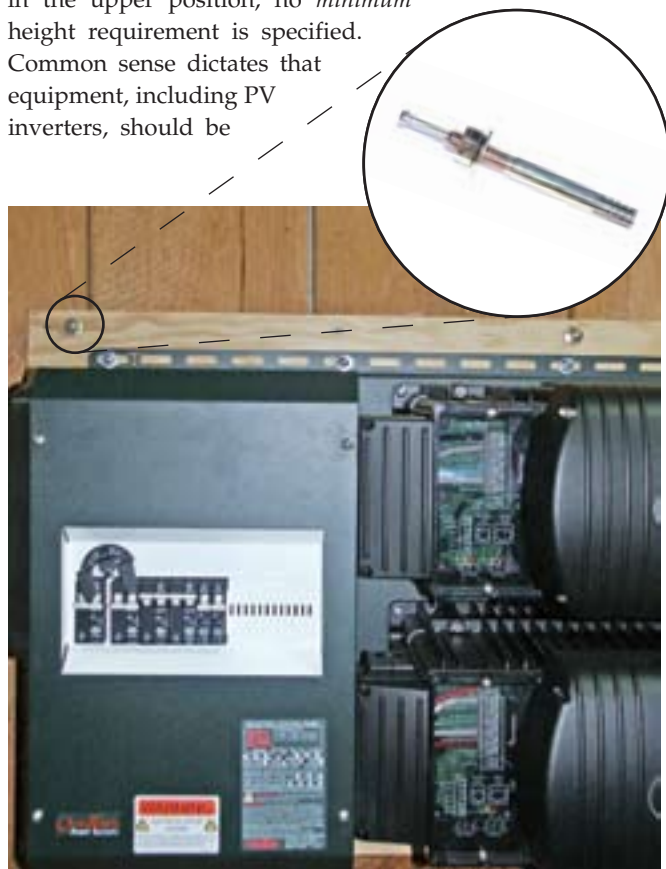
Equipment Mounting

PV inverters, even in residential-sized systems, can weigh more than 100 pounds. These inverters—as well as the

various disconnects—should be firmly attached to the walls with anchors connecting the equipment to the wall studs or other internal load-bearing members. Lag screw and conduit penetrations should, of course, avoid any electrical wiring or plumbing in the wall cavity.

While the NEC (404.8) requires that the center of the grip on the disconnect handles be no higher than 6 feet, 7 inches in the upper position, no *minimum* height requirement is specified.

Common sense dictates that equipment, including PV inverters, should be



Inverter power panels are heavy, and need to be securely mounted. Here, expansion bolts (inset) are used to fasten the panel to a wood-over-masonry wall.

mounted high enough to prevent splashing water or mud from entering. Some PV inverters have minimum space requirements below for ventilation. Access panels and fittings must be accessible so that electrical connections can be easily reached.

The distance between disconnects associated with the term “grouping” is left to the AHJ, and the allowed distance may be anywhere from a few feet to several yards. Since inverters must have AC and DC disconnects to allow for safe service and removal, it’s appropriate to locate these disconnects adjacent to the inverter. While some inverters have internal disconnects, the AHJ must determine whether or not the inverter can be safely removed for service using these internal disconnects, or whether external disconnects must also be required. If the inverter is mounted on the opposite side of a wall from the main PV DC disconnect or far from the back-fed breaker in the main AC load center, additional “servicing” disconnects are generally required adjacent to the inverter.

When *all* of the PV-related equipment is grouped together—including the PV DC disconnect, the inverter, any utility-required disconnect, and the main load center for the dwelling—a minimum number of disconnects can be used, since all equipment is on one wall and is in close proximity.

Batteries

A comparatively small number of PV systems, both off grid and utility interactive, use batteries for energy storage. Two general categories of batteries are commonly used in renewable energy systems—flooded, lead-acid (LA) and sealed, valve-regulated, lead-acid (VRLA) batteries. Battery interconnect cables should be checked periodically for both tightness and corrosion. Batteries should always be installed in a manner that does not allow inadvertent contact with any exposed, energized terminals.

Flooded, lead-acid batteries require regular watering of the cells. In general, flooded batteries should be contained in battery boxes that allow for controlled access, preventing unqualified people from coming into contact with the battery tops or the energized contacts. Lockable, heavy-duty plastic toolboxes work well, and also help contain electrolyte that could leak out if the batteries are overcharged. Flooded, lead-acid batteries outgas water vapor, some sulfuric acid fumes and, when charged vigorously, hydrogen and oxygen gases. Small ventilation holes in the top of the battery box will allow hydrogen gas to escape, and boxes should be located in a well-vented area, such as a garage or utility shed. Venting manifolds are generally not required.

Conduit penetrations into battery boxes containing flooded LA batteries should be made into the sides of the container, below the tops of the batteries. This will minimize the possibility of any hydrogen gas (which rises) entering the conduit.

VRLA batteries are easier to maintain, and generally only need their terminals and busbars protected from accidental contact using insulators supplied by the manufacturer. Under proper charging regimes, VRLAs generally do not release gas fumes, and locating them in containers is normally unnecessary.

Battery enclosures protect individuals from accidentally coming into contact with energized terminals and cables.



Clearances

NEC Section 110.26 defines the clearances for electrical equipment that may need to be serviced when energized. Such equipment might include the PV DC disconnect, the inverter, and any batteries. The 6-inch depth allowance in 110.26(A)(3) allows some leeway, but the AHJ will evaluate each installation. This is particularly true when the inverter has been placed above batteries that are located on the floor. The inverter requires a 6.5-foot clearance from the floor, and the batteries may protrude no more than 6 inches in front of the inverter. The batteries require the same clearance, but since the inverter usually has less depth than the batteries, it's generally not an issue.

Some inverters have access requirements from the sides, and this may create additional space requirements. Also, the 90-degree opening requirements for doors and access panels may dictate additional space.

Summary

With the use of exterior or interior conduit runs, and the use of surface-mounted inverters and disconnects, the materials, techniques, and workmanship requirements for a PV installation resemble a commercial electrical installation more closely than a residential one. Excellent workmanship will give the inspector a good first impression. Make your PV system shine, put a smile on the inspector's face, and above all, be safe!

Other Questions or Comments?

If you have questions about the NEC or the implementation of PV systems that follow the requirements of the NEC, feel

free to call, fax, e-mail, or write me at the location below. See the SWTDI Web site (below) for more detailed articles on these subjects. The U.S. Department of Energy sponsors my activities in this area as a support function to the PV industry under Contract DE-FC 36-05-G015149.

Access

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The 2005 *National Electrical Code* and the *NEC Handbook* are available from the National Fire Protection Association (NFPA) • 800-344-3555 or 508-895-8300 • www.nfpa.org

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Use your "Windows" computer to read all the regular data and program all functions. The website has information for you techies on how to set up, graph and analyze the emailed data so you can diagnose most common system problems without travelling to the site.

PentaMetric system with computer interface only is about \$320. LCD Display unit (above) additional \$199. See website for more info.

Your PV Installer— *Just a Click Away?*

Don Loweburg

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In her recent article, “Hiring a PV Pro” (HP114), Laurie Stone stressed the importance of finding and working with a qualified local installer when purchasing and installing a solar-electric (photovoltaic; PV) system. In addition to recommending the local yellow pages, Stone also suggested several Web-based search lists for finding local installers. Because finding a qualified installer is so important, I evaluated and compared a few of her recommended sites, as well as some others.

Solar Sleuthing

The American Solar Energy Society (ASES; www.ases.org) is a nonprofit advocacy organization—not a commercial enterprise. Although the site does not list contractors or installers, it does provide a link from its home page to a list of ASES chapters across the country. Most of the chapter listings include Web links, where you can generally find member

listings, including installers. However, this may take some poking around, as each chapter’s site is organized differently, and no consistent format is followed.

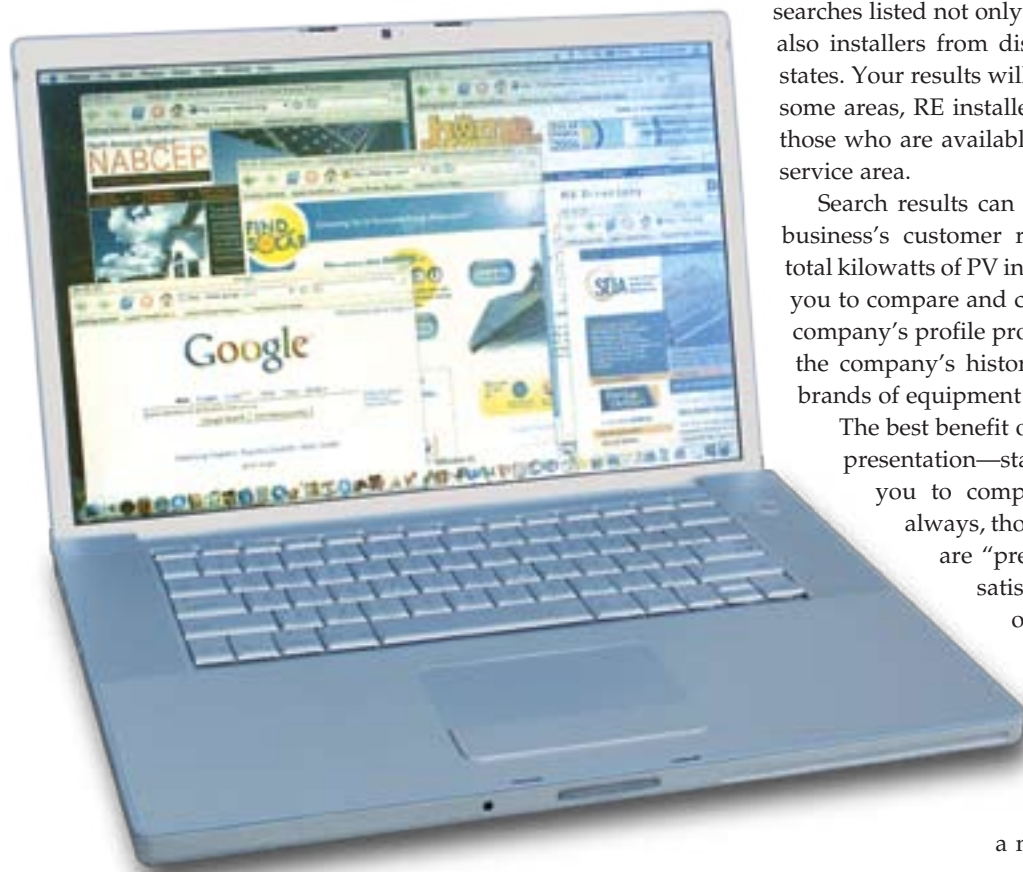
Away from your computer, you can also find sponsors listed in the programs associated with the National Solar Tour that ASES chapters conduct each fall. The tour is valuable to you as a prospective PV system purchaser since it allows you to check out functioning PV systems, and ask questions of their owners and installers.

Find Solar (www.findsolar.com) is a commercial site supported jointly by ASES, Solar Electric Power Association, Energy Matters LLC, and the U.S. Department of Energy. Their home page offers a simple, easy-to-navigate menu of linked buttons. Click on “Find a Solar Pro” to search for a local installer or to find a specific equipment supplier.

Simply select your state and county from two pull-down menus. Although the selection criterion is based on the county you enter, the list displayed is not necessarily “local.” My searches listed not only installers in the county I selected, but also installers from distant counties—and even from other states. Your results will vary, depending on your location. In some areas, RE installers are still few and far between, and those who are available make up for this by having a wide service area.

Search results can be sorted by a range of criteria—the business’s customer rating, number of systems installed, total kilowatts of PV installed, and year registered—allowing you to compare and contrast each installer. Clicking on the company’s profile provides additional information, such as the company’s history, customer review summaries, and brands of equipment offered.

The best benefit of this site is its slick organization and presentation—standard formatting and layouts allow you to compare installer information easily. As always, though, buyer beware—although listings are “pre-screened” and also report customer satisfaction ratings, this site largely relies on the honesty of its listers to present accurate information about their businesses, and only “minimal checks are made to help ensure the survey system is not being manipulated or receiving false or inaccurate information.” As a nod to protecting consumers, though,



they do provide excellent overall tips for selecting a “Solar Pro,” via a link that’s accessible on the search results page.

The North American Board of Certified Energy Practitioners (NABCEP; www.nabcep.org) maintains a list of more than 250 certified PV installers who meet the rigorous NABCEP field experience and education requirements, and pass a comprehensive written exam. The certification process is intended to be the best possible assurance that a PV installer is experienced and qualified. A link on the home page brings up a list of all NABCEP-certified PV installers, listed alphabetically by state. Only basic contact information (name, address, phone number, and e-mail address) is provided for each NABCEP certificant. Presently, “sort by state” is the only available search criteria. As the number of NABCEP-certified installers increases, there will be a need to refine the search capabilities to the local level.

The Solar Energy Industries Association (SEIA; www.seia.org), a trade organization that promotes solar technologies nationally, also works with fourteen state chapters whose members consist primarily of solar contractors. To find these contractors, click on the “About SEIA” link at the top of SEIA’s home page. You’ll find a sortable listing of members in the national organization, or select “State Chapters” to open a listing of all the state SEIA chapters. Click on a chapter’s Web site to find member contractors in that state or region. Individual chapter Web sites vary in format and organization, and finding an installer can require some sleuthing. SEIA sites generally limit listings to their members, who are unscreened.

Finally, as an experiment, I performed a Google search, which yielded surprisingly good results. A typical search query might use “solar electric” for keywords, plus your city and state. In fact, this may be the best of all the resources I tested for quickly finding a local installer, though the listings may be far from complete. Without professional screening, membership qualifications, or customer ratings, a Google search offers few details beyond an installer’s contact

information to help you make an informed decision. What it does offer is quick, but partial, results and accompanying maps that can take you to the doorstep of a potential installer, for a face-to-face meeting.

Clicking—& Checking

No matter which search approach you use, consider all results as preliminary. The online search process can be likened to throwing a net into the sea. You might catch a lot, but find only a few “keepers.”

Some of the sites listed here have disclaimers intended to release them from legal liability for the accuracy of the listing results displayed, and all rely on the customer to research the listings further. The ultimate responsibility for any choice falls on you, the customer. And no matter what source or list you use, in the end, you must rely on your own best judgment. Most of the installer profiles on these sites are self-reported, depending solely on the installer’s integrity to provide accurate information.

So before you sign a contract, make sure the company you’re considering has experience installing the type of RE system you want. Inquire about the number of years they’ve been in business and what licenses they hold. Request both business and client references—and check them.

If you already know what you want, don’t be afraid to get bids from several different installers, and don’t forget to weigh their experience and evaluate the quality of their installations while you’re comparing prices. Check with your state or county to make sure the person you choose is properly licensed or certified to do the job. And, if you plan to take advantage of incentive programs to help offset the costs of your system, make sure whomever you choose qualifies as an approved installer for those incentive programs.

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Governing the Climate

Michael Welch

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Human-caused climate change is affecting our global environment, and the effects are likely to increase. While definitive changes caused by global warming are difficult to predict, we can anticipate dryer and hotter summers, less predictable and wilder storm seasons, and a gradual rising of sea levels as glaciers and polar ice continue to melt. The good news is that we still have opportunities to avert significant disruptions to both our global environment and economy by reversing the major cause of the problem—excessive carbon dioxide (CO₂) in the atmosphere.

Ultimately, reversing carbon emissions is the responsibility of each of us—in our own energy choices and consumption, our behavior as consumers, and how we communicate with and hold our leaders accountable. Here is a synopsis of what our leaders and others have been doing to stem the world's rapidly increasing carbon dioxide emissions.

The International Scene

The Kyoto Protocol amended the United Nations Framework Convention on Climate Change, and opened for signature in 1997. It went into effect February 2005 with the objective of stabilizing greenhouse gas concentrations in the atmosphere at a

level that would, according to the protocol, “prevent dangerous anthropogenic interference with the climate system.”

The protocol's goal was to have industrialized countries decrease their CO₂ emissions by 5.2 percent from 1990 levels, and accomplish this by 2050. (Other commonly accepted strategies, similar to California's recently passed law, call for reduction of worldwide levels to 80 percent below 1990 levels by 2050.)

The protocol is a cap and trade system, in which each country in the agreement has an agency that sets (caps) the maximum amount of global warming emissions that can be released at the country's current rate. These agencies then distribute the pollution credits to all industries, the total of which does not exceed the amount needed for the country to stay within compliance. Polluters exceeding their credit allocations have to purchase additional credits, which can only be acquired from facilities that have reduced their emissions enough to have additional credits. This sets up a market for carbon emissions trading; facilities that have credits can sell them at market rates to those that need them. The incentive to reduce CO₂ emissions is based on the profit motive, while the overall reduction goals are completely reliant on the gradual reduction of the cap.

Kyoto Protocol Participation Map (2005)



Another noteworthy international effort is the Intergovernmental Panel on Climate Change (IPCC), which reviews worldwide research and issues regular assessment reports, relying on peer-reviewed and published scientific literature. Generally, governments respect the findings of the IPCC as authoritative, and the IPCC's *Second Assessment Report: Climate Change 1995* formed the basis for negotiations of the Kyoto Protocol.

Big Government, Little Change

The U.S. government is one of only two signing countries that has not ratified the Kyoto Protocol (the other is Australia). That makes our involvement merely symbolic. Ratification is required to make the agreement binding and to formalize our commitment to its objectives.

But other initiatives are slowly winding their way through Congress. The McCain-Lieberman Climate Stewardship Act would cap U.S. CO₂ emissions at 2000 levels by 2010, but leaves lots of loopholes for exempting agriculture and residences from these requirements, and includes strong support for developing coal gasification and nuclear energy. Although the original bill was killed in 2003, it was reintroduced with modifications in 2005, and is still in committee.

Perhaps the most promising federal bill is the Waxman Safe Climate Act (HR 5642), which was introduced in June 2006. If passed, it would freeze U.S. greenhouse gas emissions in 2010 at the 2009 levels through a cap and trade system. Beginning in 2011, it calls for cuts in emissions by roughly 2 percent per year, with the goal of reaching 1990 emissions levels by 2020. After 2020, it specifies reducing greenhouse gas emissions by roughly 5 percent per year, with the result that, by 2050, emissions will be 80 percent lower than 1990 levels. This is on target with what the consensus of the scientific community has determined as necessary. Bill author Representative Henry Waxman from California is lining up sponsors and support, so please be sure to contact your representatives in Congress and ask them to sign on as sponsors to the bill (see sidebar).

It is interesting to note that things have been heating up for politicians, especially previous to the 2006 Congressional campaigns. One interesting approach was Greenpeace's Project HotSeat. The project's objective was to "light a fire under candidates in six key voting districts" to increase congressional support for curbing climate change. According to Vermont's *Burlington Free Press*, "Project HotSeat helped organize a five-day global warming march and rally...with several [non-Congressional] candidates signing a pledge to get serious about counteracting global warming..." Greenpeace's objective is to "create in Congress champions of global warming solutions."

The U.S. Climate Change Science Program is a fairly new collaborative interagency program developed to improve climate-related technology development throughout the federal government. While it is a bit disconcerting to turn such things over to an organization subject to the whims of whatever administration happens to be in power, it is a framework under which good work and coordination of effort could be accomplished with the right direction.

More Climate Change Action Resources

International

United Nations Framework Convention on Climate Change • <http://unfccc.int>

Intergovernmental Panel on Climate Change • www.ipcc.ch

Federal

Waxman's Safe Climate Act of 2006 (H.R. 5642) • www.house.gov/waxman/safeclimate

U.S. Climate Change Science Program • www.climatechange.gov

State

Regional Initiatives • www.pewclimate.org

California Climate Action Portal • www.climatechange.ca.gov

California's AB32 analysis • www.mofo.com/news/updates/files/update02237.html

Local

Cities for Climate Protection • www.iclei.org/ccp

U.S. Mayors Climate Protection Agreement • www.seattle.gov/mayor/climate

Sierra Club Cool Cities Campaign • www.coolcities.us

Clinton Climate Initiative (for large cities) • www.clintonfoundation.org

Additional Resources

Evangelical Environmental Network • www.creationcare.org/resources/climate

Greenpeace's Project HotSeat • <http://members.greenpeace.org/hotseat>

MTV / Energy Action Coalition • www.mtv.com/thinkmtv • www.climatechallenge.org

Union of Concerned Scientists • www.ucsusa.org/global_warming

Green House Network • www.greenhousenet.org

Find a climate change speaker near you • www.greenhousenet.org/speakers_network.htm

Climate Ark—news, links, blogs, & documents related to climate change • www.climateark.org

Union of Concerned Scientists • www.ucsusa.org/global_warming

See also "RE-Sources: Global Cooling" in *HP115*

State Stakeholders & Local Action

Several regional initiatives are developing cap and trade programs for greenhouse gas emissions, and supporting clean energy, energy efficiency, and conservation efforts. These regional initiatives include:

- Western Governors' Association: Clean and Diversified Energy Initiative
- West Coast Governors' Global Warming Initiative
- Powering the Plains
- New England Governors: Climate Change Action Plan
- Southwest Climate Change Initiative
- Regional Greenhouse Gas Initiative

Individual states are also working on addressing climate change problems. But probably the most remarkable effort comes out of California, where the Global Warming Solutions Act (AB32) was passed by both legislatures in August 2006, and signed into law in September. The Act makes mandatory the 2005 executive order signed by Governor Schwarzenegger that reduces greenhouse gas emissions to 2000 levels by 2010, 1990 levels by 2020, and, by 2050, to 80 percent below 1990 levels. According to California State's Climate Action Team, by implementing these targets, this bill will create \$4 billion in income and 83,000 jobs.

One of the most interesting local programs, Cities for Climate Protection (CCP), helps local governments attain carbon reduction plans by going through a five-step program. More than 160 local governments in the United States have joined, and more than 500 worldwide.

With the CCP's five-step program, and their detailed instructions and support, local governments inventory local greenhouse gases, set reduction targets, and then create, implement, and monitor a reduction plan. The program is fairly new, so very few cities are far enough along for measurable results. But CCP is growing quickly and its participants feel the program is going to make a big difference fairly quickly.

Closer to Home

Folks from all walks of life are taking action to address global warming, along with the virtual and real communities they belong to. This fall, MTV teamed up with the Energy Action Coalition to sponsor their "Break the Addiction Challenge" on college campuses around the country. The contests offer prizes rewarding both individual and group efforts, but the main focus is getting college campuses to develop clean energy policies and purchase their energy from renewable sources.

Grassroots effort is key to curbing the effects of global warming, and nearly every community has nearby committees and groups that are promoting education and advocacy relating to climate change. You can plug in by joining local organizations that work on environmental and energy issues, and take personal action with these simple goals:

- Replace five incandescent lightbulbs in your home with compact fluorescents. This simple step can save up to 2 tons of carbon dioxide emissions and \$150 in electricity over the life of the bulbs.
- At least one day a week (more often is better!), carpool, walk, bike, or take public transportation.
- Keep up to date, and educate yourself and others about global warming. A good source for regularly updated info is the Union of Concerned Scientists Web site (see sidebar). A great source for tracking climate change legislation is the Pew Center on Global Climate Change at www.pewclimate.org.
- Keep your government representatives' feet to the fire in supporting climate change bills by contacting them directly and using the letters section of your local newspapers.

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Excuses...

Unreal Roadblocks to Renewable Energy

Ian Woofenden

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Derivation: "Excuse" is from Latin excusare, cause, explanation.

I meet many people who are new to the idea of renewable energy (RE) and, in talking with them, hear a lot of excuses for not going for it. Their justifications run the gamut from technical, social, and aesthetic reasons, to just plain ludicrous ones. Here's a sampling:

RE systems "don't work." This one is easy for me to refute, since I've been depending on renewable energy systems for my family's electricity for more than 20 years. But it's good to ask and listen, to find out what second-rate experiences folks have had, and let them know that past failures don't mean that present-day RE systems don't work. Of course, reading *Home Power* is a good antidote for this excuse, since we profile first-class, working systems in every issue.

RE systems aren't efficient enough. Efficiency is somewhat of a red herring with solar and wind energy systems, since the fuel is free and readily available. With PV systems, for instance, efficiency simply relates to how much space the array will require. This is much less important than the cost of the delivered energy. Improving efficiency comes at a cost, so unless efficiency gains come with cost reductions, I'll choose the lowest cost per delivered watt-hour, unless space is at a premium.

RE systems are too expensive. While the cost of a system can be relatively easy to get a handle on, estimating its true value and impact can be more elusive to quantify. It's curious to me that although we base *very* few decisions in our lives solely on economics, energy devices tend to be held to this standard exclusively. We don't buy food, clothing, furniture, or vehicles on their economy alone, but rather on their complete value, which may include health, comfort, and aesthetic preferences, among others. Our energy decisions should be no different—we should consider the environmental and social consequences, the subsidies propping up dirty energy technologies, and what legacy we're leaving our kids and grandkids.

My house isn't ready. Practical objections often center on waiting until a home's roofing is ready to replace or has been replaced. But modern racking options allow



easy removal and replacement of PV modules when it's time to replace the roofing. Pole and ground mounts are also options that should be considered and, depending on your site, can be the best choices. Other objections have to do with the load-bearing capability of the roof to support solar hot water collectors or the strength of floor framing for supporting batteries. While these may be real issues, they are not deal-breakers, merely projects to be tackled in preparation for system installation.

Wind turbines are too much trouble. This excuse includes objections about sound, vibration, tower height, and birds. While using wind energy does take considerable care and involvement, all of these objections can be dealt with through proper siting and design. More outlandish excuses include assertions that wind generators scare away the worms in the ground around the tower, cause epilepsy, and interfere with the communications systems that protect our homeland security. Of course, perhaps folks with these fears *should* avoid wind energy...

RE systems are ugly. These folks wish that PV modules came in just the right color to match their home's trim. Or they think that wind turbines and towers clutter a landscape. Even some homeowners' association bylaws prohibit certain solar energy equipment on "aesthetic grounds." A Latin aphorism states, "De gustibus non disputandum est"—there's no accounting for taste.

My taste runs toward pollution-free energy that's democratically distributed to everyone on the planet—that seems truly beautiful to me. I think we need to continue to brag up solar energy systems as beautiful, while at the same time focusing on new, more aesthetic installation options. And it doesn't hurt to mention the ugliness of nonrenewable energy plants—not only their present ugliness, but the ugliness of their long-term effects on our health, society, and environment.

The bureaucracy makes it difficult to use RE systems. This can refer to punitive local regulations or uncooperative utilities. Or it can be the lack of incentives and subsidies that is used as an excuse. Whatever the hurdles, we've seen over and over again that committed and determined people can overcome them. And after the first person in an area perseveres, it's easier for everyone who follows.

RE systems are dangerous. "They can kill utility linemen." Not true! "You can get electrocuted or burned." True of many household systems, RE or not—but only if they are improperly installed or used. "Batteries give off dangerous gasses." True, but the precautions are straightforward.

Other such excuses crop up now and then. The big picture is that modern RE systems, installed and used in safe, code-compliant ways, are just as safe as your car, furnace, or office equipment—things you use every day.

There's not enough sun where I live. I hear this a lot because I live in the "cloudy" Northwest. Although we do get cloudy weather in the winter, we get lots of sun in the other seasons. And with annualized net metering, we can sell our surplus solar energy to the utility all summer, and

use the credit when it gets cloudy. Sure, Arizona gets more sun than we do, but not ten, five, or even twice as much as most places. It's worth capturing the renewable resources available to you, and few places truly have "not enough sun."

No More Excuses

Sometimes I think there's some pathology afoot when I see the lengths people will go to talk themselves into *not* doing anything with renewable energy. But perhaps it's just a human resistance to change. An acquaintance involved in substance abuse education says that many addicts will choose jail over rehabilitation because they are familiar with jail, while rehab is new and unfamiliar to them.

So if you're on the fence about renewable energy, get yourself familiar with the reality of these amazing technologies. Change isn't so hard when you know why you need to change, how to change, and that change will make your life better!

Access

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For more discussion of these and other excuses, see "Clearing the Air: Home Power Dispels the Top RE Myths" in HP100.

Heard any outrageous RE excuses? Send them to me, and you may see them in print.



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A Day in the Life

Kathleen Jarschke-Schultze

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I find myself trying to explain to the curious what living off grid on renewable energy is like. Having lived beyond the grasp of the utility lines for more than 20 years, I realize there are many aspects of off-grid living that have become automatic for me.

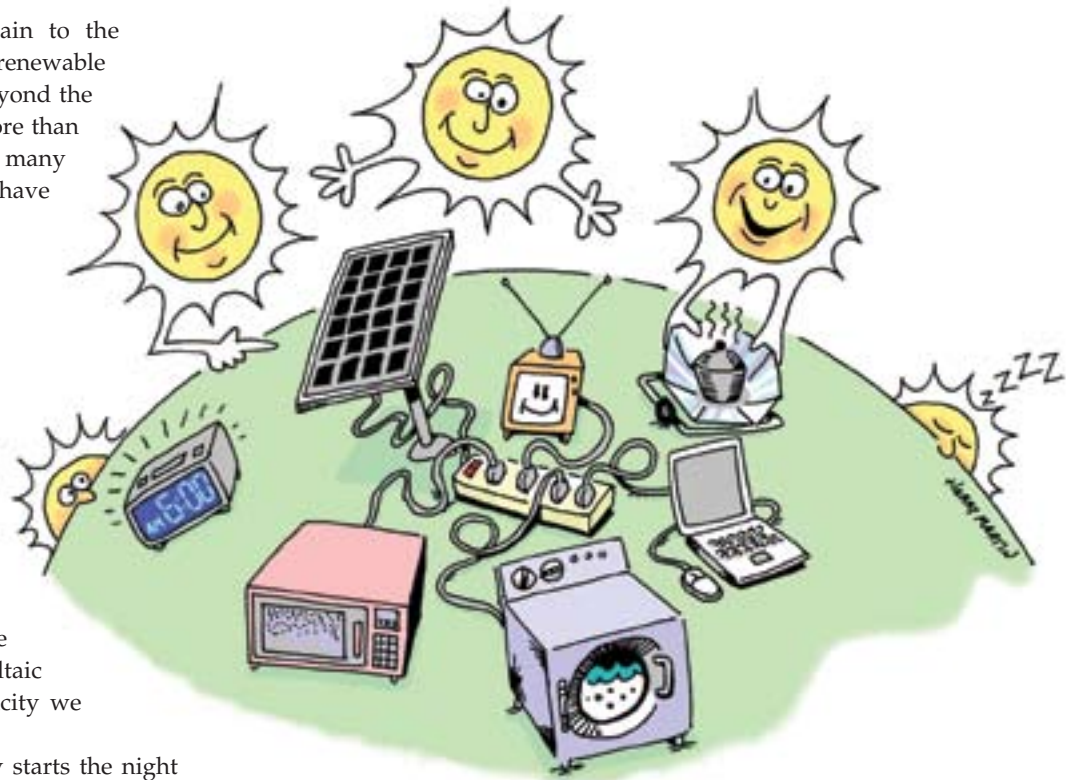
Free Fall

In describing a late autumn day, I'm hoping to give an idea of our typical energy-use profile. I have described our winter and springtime microhydro-powered life in previous columns. In the fall, when our seasonal creek has dried up and the wind in our little canyon is occasional rather than daily, we rely mainly on our photovoltaic modules to give us the electricity we need.

"A day in the life" actually starts the night before. In the evening, as the ambient and house temperatures equalize, we open all the windows in the house. This allows the heat that's accumulated in the house to dissipate overnight. This is also when I take any frozen food I will need for tomorrow's dinner out of my Sun Frost F10 freezer in the basement, and put it upstairs in my Sun Frost RF16.

Bright Sunshiny Day

The battery-powered alarm clock goes off at about 6 AM, give or take 30 minutes, depending on the plan of action for the day. My husband Bob-O gets up and makes coffee. He switches on the fused plug strip mounted above the kitchen counter, then fills and flips on the coffee grinder. He flips on the plug strip attached to the wall between the propane stove and the microwave. This automatically turns on a bar-type fluorescent light above the stove, and sends electricity to the Piezo-electric lighters and the clock/timer on the stove. He starts the kettle to boil and feeds Emma the Airedale terrier. We watch the local news and weather on the TV in the bedroom. This gives us an idea of how to dress and plan our day.



The Right Track

After coffee, and with some sort of plan or project in mind, we ready ourselves for action. While Bob-O checks his e-mail, I glance at the system meters mounted on our dining room wall. The top one shows the amps coming from the PVs. In the morning, with full sun, we usually see 35 amps coming to our 24-volt battery system. As the sun gets higher, that increases to about 50 amps. The second meter tells me the battery bank's state of charge (SOC)—how full the batteries are—as a percentage. The typical SOC first thing in the morning in late fall is between 77 and 85 percent.

I like to let the batteries get a little more charge before I start chores that use a lot of electricity. If the food for tonight's dinner is still frozen, I put it on a thawing tray on the kitchen counter. We do some outside work before the day heats up. That could be harvesting vegetables from the garden, stacking firewood, pruning vines or trees, trimming weeds, or whatever outside work needs to be done.

Water Works

The solar pump in our well delivers the water to two 1,350-gallon tanks up the hillside. We never completely empty the tanks. When the tanks start to overflow, we turn on various drip lines and weeper hoses around the yard. A map of our watering system is drawn on a large, white metal board next to our front door. On it, I have marked all the hose bibs and what they are watering. When we turn on a faucet, we mark that bib on the map with a magnet. Then, as the sun sinks behind the hills, we know exactly where to go to turn the water off.

Chef Kathleen

Back in the house, it is noticeably cooler with the windows and shades drawn. I prepare our dinner's main dish to put into the Solar Chef oven that sits out by the arbor. Perhaps I'm preparing a whole chicken. I finely chop some fresh parsley, oregano, and sage, make a slurry of olive oil, herbs, coarse ground sea salt, and fresh ground pepper, and massage this onto the rinsed and dried chicken. Using my black metal pan with a lid, I place some onions and carrots from the garden into the bottom, and place the chicken on top. If I have smallish potatoes from the garden I put these around the bird. The lid goes on and the pot goes out to the Solar Chef. I like to take my potholders out to the cooker and leave them there, so they are handy whenever I check dinner's progress.

Housewifery

I see that the battery SOC is in the 90 percent range now, so I start a load of laundry. I have a Frigidaire front-loader in the basement. I always use cold water and a liquid biodegradable soap.

As I pass the battery bank I can hear the batteries gently bubbling. The gassing tells me that they are charging well and approaching full capacity. I go upstairs and start a load of dishes in the dishwasher. This will use a lot of energy, but it is early on a sunny day and the batteries will have time to recharge before the day is done. This is prime time for electricity usage—right when it is being generated. If you're making extra energy and not using it, you are wasting it.

A couple of times during the day, I will go out and refocus the Chef to keep our dinner cooking. When the laundry is done, I bring it upstairs and out onto the deck where Bob-O has erected an umbrella-shaped revolving clothesline for me. I can

easily hang two loads of clothes on it at once. But two is as many loads as I will do in one fall day. Our house water system is fed by our spring, which is slow-flowing at this dry time of year.

We Time

The warm afternoon finds us spending a little free time. Reading, napping, or surfing the Web is the norm. If I turn on our big plasma TV, I flip on the fused plug strip first. This turns on the satellite receiver automatically. Then I use the remote to turn on the TV. All of our electronic devices are on fused plug strips. This avoids unnecessary phantom loads. Flipping on a plug strip before I turn on an appliance or device has become automatic.

End of Day

As the afternoon ends, I bring in the clothes from the clothesline, fold them, and put them away. I take the dishes from the dishwasher and put them in cupboards. I bring in the chicken and vegetables from the Chef. We round out the meal with a simple salad of sliced tomatoes and cucumbers from the garden, with a little olive oil, red wine vinegar, salt, and pepper. Add a cool bottle of our own pinot noir from the basement, and dinner is served.

As twilight comes, we open all the windows and shades to let the now-cooler breeze flow through the house. The coffee cups, French press, and utensils are set out on the counter, ready for the next morning. Our day is done.

If it's a weekday, I get Bob-O out the door and to a job. Then I spend several hours doing office work, paying bills, invoicing clients, shipping product, and fielding phone calls. I have a cordless headset that allows me to roam my home and yard freely while still answering our business lines. One of our dealers always tries to guess where I am by the background sounds (creek, chickens, etc.) Those days I do about the same things, I just fit it all around the demands of the biz.

And, of course, if Bob-O is gone, something is likely to break, crack, leak, smoke, or beep uncontrollably at me...

Access

Kathleen Jarschke-Schultze is pursuing the perfect pinot noir at her home in northernmost California. c/o *Home Power* magazine, PO Box 520, Ashland, OR 97520 • 800-707-6585 • kathleen.jarschke-schultze@homepower.com



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A photograph of Tom Hanks standing in a forest of birch trees. He is wearing a red vest over a light blue shirt and blue jeans. The text "I believe in Conservation" is written in a white, handwritten-style font across the middle of the image.

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Sandia National Laboratories PV systems Web site. Design practices, PV safety, technical briefs & battery & inverter testing • www.sandia.gov/pv

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Arcata, CA. Workshops & presentations on RE & sustainable living. Campus Center for Appropriate Technology, Humboldt State Univ. • 707-826-3551 • ccat@humboldt.edu • www.humboldt.edu/~ccat

Hopland, CA. Workshops on PV, wind, hydro, alternative fuels, green building & more. Solar Living Institute • 707-744-2017 • sli@solarliving.org • www.solarliving.org

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Carbondale, CO. Workshops & online courses on PV, pumping, wind, RE businesses, microhydro, SDHW, heating, alternative fuels, green building, women's PV courses & more. Solar Energy Intl. (SEI) • 970-963-8855 • sei@solarenergy.org • www.solarenergy.org

FLORIDA

Melbourne, FL. Green Campus Group meets monthly to discuss sustainable living, recycling & RE. Info: fleslie@fit.edu • <http://my.fit.edu/~fleslie/GreenCampus/greencampus.htm>

IOWA

Iowa City, IA. Iowa RE Assoc. meetings. Call for times. I-Renew • 319-341-4372 • irenew@irenew.org • www.irenew.org

ILLINOIS

Mar. 16–18, '07. Chicago, IL. Consumer Alternative Fuel & Energy Efficiency Expo. • www.consumeralternativefuels.com

MASSACHUSETTS

Mar. 13–15, '07. Boston, MA. Building Energy '07. Conference & trade show for RE, planning & building professionals. Workshops, speakers & exhibitors. Info: Northeast Sustainable Energy Assoc. • www.buildingenergy.nesea.org

MICHIGAN

Dec. 9, '06. Dimondale, MI. Introductory Solar Heating. Info: Great Lakes RE Assoc. • 517-646-6269 • jennifer.malinowski@glrea.org • www.glrea.org

West Branch, MI. Intro to Solar, Wind & Hydro. 1st Fri. each month. System design & layout for homes or cabins. Info: 989-685-3527 • gottter@m33access.com • www.loghavenbbb.com

MINNESOTA

Jan. 25–28, '07. Winona, MN. Frozen River Film Festival. Films & speakers on RE, sustainable communities, climate change & more. Info: www.frff.org

MONTANA

Whitehall, MT. Seminars, workshops & tours. Straw bale, cordwood, PV & more. Sage Mountain Center • 406-494-9875 • www.sagemountain.org

NEW MEXICO

Six NMSEA regional chapters meet monthly, with speakers. NM Solar Energy Assoc. • 505-246-0400 • info@nmsea.org • www.nmsea.org

NEW YORK

Apr. 7, '07. Photo contest deadline for the 2007 New York State Envirothon, which this year focuses on RE. Info: www.envirothon.org

NORTH CAROLINA

Saxapahaw, NC. Solar-Powered Home workshop. Solar Village Institute • 336-376-9530 • info@solarvillage.com • www.solarvillage.com

OREGON

Cottage Grove, OR. Adv. Studies in Appropriate Tech., 10-week internships. Aprovecho Research Center • 541-942-8198 • apro@efn.org • www.aprovecho.net

PENNSYLVANIA

Philadelphia Solar Energy Assoc. meetings. Info: 610-667-0412 • rose-bryant@verizon.com

TEXAS

El Paso Solar Energy Assoc. Meets 1st Thurs. each month. EPSEA • 915-772-7657 • epsea@txses.org • www.epsea.org

Houston RE Group quarterly meetings. HREG • hreg@txses.org • www.txses.org/hreg

WASHINGTON STATE

Apr. 25–27, '07. Guemes Island, WA. Solar Hot Water workshop. Classroom, tours & installation. Info: See listing below.

Apr. 30–May 5, '07. Guemes Island, WA. Wind-Electric Systems workshop. Design, system sizing, site analysis, safety issues, hardware specs & a hands-on installation. Info: See listing below.

May. 7–12, '07. Guemes Island, WA. Homebuilt Wind Generators workshop. Learn to build wind generators from scratch, incl. carving blades, winding alternators, assembly & testing. Info: See SEI in Colorado listings. Local coordinator: Ian Woofenden • 360-293-5863 • ian.woofenden@homepower.com

WISCONSIN

Custer, WI. MREA '06–'07 workshops: Basic, Int. & Adv. RE; PV Site Auditor Certification Test; Veg. Oil & Biodiesel; Solar Water & Space Heating; Masonry Heaters; Wind Site Assessor Training & more. MREA • 715-592-6595 • info@the-mrea.org • www.the-mrea.org

INTERNATIONAL

Internet courses: PV, green building & intl. development. Solar On-Line (SOL) • 720-489-3798 • info@solenergy.org • www.solenergy.org

Internet courses: PV Design & Solar Home Design. Solar Energy Intl. online. Info: See SEI in Colorado listings.

AUSTRIA

Feb. 28–Mar. 2, '07. Wels. World Sustainable Energy Days. Conferences on energy efficiency, green electricity, renewable HVAC & more. Info: O.Ö. Energiesparverband • 43-732-772-014-380 • office@esv.or.at • www.esv.or.at

BELIZE

Jan. 8–13, '07. San Pedro Columbia. PV system design & installation, with PV pumping. Classroom & hands-on work. Info: Maya Mt. Research Farm • info@mmrfbz.org • www.mmrfbz.org

CANADA

British Columbia. BC Sustainable Energy Assoc. meetings at chapters throughout province • www.bcsea.org/chapters

Calgary, AB. Alberta Sustainable Home/Office. Open last Sat. of every month, 1-4 PM, private tours available. Cold climate, conservation, RE, efficiency, etc. • 403-239-1882 • jdo@ecobuildings.net • www.ecobuildings.net

CHINA

Apr. 10-12, '07. Shanghai Intl. Wind Energy Exhibit & Conf. Info: Shirley Sun • 86-01-30-42-113-676 • chinapower2007@yahoo.com.cn • www.cwee.com.cn

COSTA RICA

Jan. 22-28, '07. Rancho Mastatal. RE for the Developing World—Hands-On. Overview of solar electricity, hot water & cooking; biogas & other RE technologies. Info: See last listing for WA State.

Feb. 2-10, '07. Durika. PV for the Developing World. Comprehensive workshop on PV. Info: See last listing for WA State.

NEW ZEALAND

Jan. 27-28, '07. Canterbury. Sustainability EXPO. PV, wind, SDHW, energy efficient building design, housing & transport, & other sustainable technologies. Info: Solar Electric Specialists Ltd. • 027-457-6527 • www.sustainabilityexpo.co.nz

NICARAGUA

Jan. 7-19, '07. Managua. Solar Cultural Course. Lectures, field experience & ecotourism. Richard Komp • 207-497-2204 • sunwatt@juno.com • www.grupofenix.org



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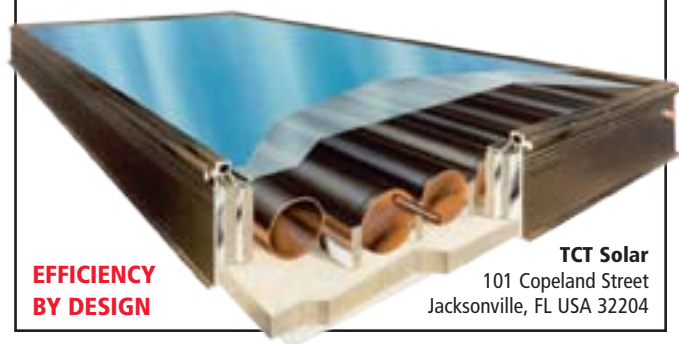
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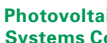


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